1989

Policy structure, output supply and input demand for US crops

Satheesh Venkata Aradhyula
Iowa State University

Order Number 8920107

Policy structure, output supply and input demand for U.S. crops

Aradhyula, Satheesh Venkata, Ph.D.

Iowa State University, 1989

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

Policy structure, output supply and input demand

for U.S. crops

by

Satheesh Venkata Aradhyula

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Economics
Major: Agricultural Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1989

TABLE OF CONTENTS

	Page
CHAPTER I. INTRODUCTION	1
Background	1
Problem	5
Objectives	8
Organization of the Study	9
CHAPTER II. POLICY STRUCTURE OUTPUT SUPPLY AND INPUT DEMAND	10
Duality	11
Profit Function	13
Aggregation	15
Flexible Functional Forms	17
Normalized Quadratic Profit Function	20
Policy Structure	22
Summary	24
CHAPTER III. THEORETICAL CROPS COMPONENT SPECIFICATION	25
Policy Instruments and U.S. Farm Programs	25
Market price supports	25
Target prices	26
Acreage controls	26
The Model Program	27
The Participation Decision	30
Non-participant	31
Participant	33
Participation	35

Paid-diversion program 41
Multiproduct Firm 43
Non-participant 44
Participant 45
Summary 46
CHAPTER IV. ISSUES IN EMPIRICAL IMPLEMENTATION 49
Policy Implementation 49
Target prices and loan rates 50
Set-aside requirements 52
Diversion payments 53
Program participation 54
Fixed Variables and Technology 59
Comparative Statics 60
Changes in target prices 61
Changes in set-aside requirements 62
Concluding Remarks 63
CHAPTER V. DATA AND ESTIMATION 65
Data 65
Output variables 70
Policy variables 71
Variable inputs 73
Fixed input: Durable farm machinery 76
Estimation 76
Estimation of participation rate equations 78
Estimation of output supply and input demand equations 79

Cholesky factorization 80

Full information maximum likelihood estimator 82

Summary 84

CHAPTER VI. EMPIRICAL RESULTS 85

Output Supply and Input Demand Equations 85

Test for convexity of profit function 95

Price elasticities of product supply and input demand 99

Nested model 101

Equations for Program Participation Rate 104

Summary 108

CHAPTER VII. POLICY ANALYSIS 110

Historical Simulation 110

Scenario Analysis 113

Target prices 113

Set-aside requirements 117

Concluding Remarks 122

CHAPTER VIII. SUMMARY 123

REFERENCES 126

ACKNOWLEDGMENTS 148

APPENDIX A 149

APPENDIX B 161

LIST OF TABLES

		Page
Table 1.1	Major crops and commodity programs in the United States, 1985-1986	2
Table 1.2	Redistributional effects of U.S. farm policies	4
Table 2.1	Summary of aggregation results	18
Table 5.1	Description of variables, units, and data sources	66
Table 6.1	Maximum likelihood estimates of output supply and input demand equations maintaining symmetry and convexity	86
Table 6.2	Cholesky values (D_{ii}) of restricted and unrestricted models	96
Table 6.3	Price elasticities of product supply and input demand evaluated at sample means	100
Table 6.4	Nested model: Price elasticities of product supply and input demand evaluated at sample means	103
Table 6.5	Ordinary least squares estimates of commodity program participation rate equations	105
Table 6.6	Estimated elasticities of participation rates	107
Table 7.1	Simulation statistics of the estimated model	112
Table 7.2	Percent changes in program participation rates under a 10 percent increase in target price	114
Table 7.3	Percent changes in production and input demand under a 10 percent increase in target price	115
Table 7.4	Percent changes in program participation rates under a 100 percent increase in set-aside requirements	119
Table 7.5	Percent changes in production and input demand under a 100 percent increase in set-aside requirements	120
Table A.1	Data used for the estimation	149

LIST OF FIGURES

		Page
Figure 3.1	Truncation of a hypothetical probability distribution of price at the guaranteed minimum price P_m	29
Figure 3.2	Factor intensities for participants and non-participants in a commodity program	36
Figure 3.3	Composite output supply curve of the firm	40
Figure 4.1	Response of program participation rate to target price and paid-diversion payment rate	58

CHAPTER I. INTRODUCTION

Background

There is a long tradition in the U.S. agriculture of managing supply to increase farm prices. Managed agricultural commodity markets continue to be a cornerstone of U.S. farm policy. These policies can be divided into two categories, the price support and set-aside domestic programs and border price control measures for trade. Price support programs for wheat, feed grains, cotton, tobacco, peanuts, sugar, rice and dairy products have generally kept the domestic prices of these commodities above the "market clearing" levels (Yanagida et al. 1987). On the other hand, tariffs, quotas and other border protection measures have insulated domestic markets, successfully keeping imports low and maintained higher domestic prices than in world markets. Sugar, beef, pork and dairy are examples of programs utilizing these trade restrictions.

During 1981-85 the U.S. government spent an average of $12 billion per year on agricultural commodity programs. This was equal to nearly half of annual average net farm income for the period. The government also provided an additional several billion dollars per year in aid that does not show up in the annual budget; tax preferences, credit provisions and guarantees, privileges to agricultural marketing cooperatives etc. (Gardner 1985). These policies constitute subsidies to production, and tend to generate domestic commodity surpluses and downward pressure on world commodity prices. However, U.S. policy also held an annual average of 30 million acres of cropland out of production during 1981-1985. This figure is equal to 9 percent of total cropland harvested. In addition, marketings of commodities like peanuts and tobacco are restricted. Thus, net effect of U.S. commodity policies on total output and world market prices is not obvious. A list of the major programs and government costs by crop are given in Table 1.1.

Table 1.1. Major crops and commodity programs in the United States, 1985-1986[a]

Commodity	Acres Planted	Farm value	Nature of program	Government Expenses
	(mil.)	($ bil)		($ bil)
Feed grains	111.79	25.40	deficiency payments acreage diversion storage subsidies	12.21
Wheat	64.73	7.64	deficiency payments acreage diversion storage subsidies price supports	3.44
Soybeans	61.58	10.57	price supports	1.60
Hay	60.42	9.44	free market	0.00
Cotton	10.23	3.99	deficiency payments acreage diversion storage incentives price supports	2.15
Flaxseed & Sunflower	3.68	0.28	free market	0.00
Rice	2.49	0.89	deficiency payments acreage diversion price supports	0.95
Sugar beet& and cane	1.87	1.51	import quotas levies	0.21
Peanuts	1.47	1.00	marketing controls price supports	0.04
Tobacco	0.69	2.49	acreage/marketing controls, price supports	0.25
Vegetables	3.22	6.84	marketing orders	0.00
Fruits & nuts	-	6.84	marketing orders	0.00

[a]U.S. Department of Agriculture, Agricultural Statistics.

Gardner (1981), Heien (1977) and Lin et al. (1981), among others, have calculated the direct and social costs of U.S. farm programs. Amidst an increasing number of farm foreclosures, low agricultural product prices and reduced farm exports there has been increased discussion of deregulating the domestic markets for commodities and researchers have tried to quantify the possible effects of deregulation; trade liberalization and reduced government involvement in the agricultural markets. USDA/ERS (1985), Food and Agricultural Policy Research Institute (1987a, 1987b, 1988), Yanagida et al. (1987), Frohberg et al. (1988), Johnson et al. (1988), and Robinson et al. (1988) are a few such studies.

Schmitz and Chambers (1986) have investigated the welfare implications of a target price-deficiency payment program for large open economies. Using a simple and stylized numerical example they calculated the deadweight loss for the U.S. wheat market. They found that the deadweight loss ranged from $75 million to $400 million under varied assumptions on domestic supply and export demand elasticities.

Gardner (1985) has developed a comprehensive study to measuring the economic consequences of U.S. agricultural policy. Using a simple supply-demand framework he estimated the short run redistributional effects for 1984-1985 of U.S. farm commodity programs. These effects were obtained by solving stylized commodity specific supply-demand models with and with out farm programs. His estimates are summarized in Table 1.2.

The effects in Table 1.2 are short run impacts, given a one or two year period adjustment. Long run supply and demand elasticities are larger and imply smaller producer gains. The aggregate long run effects on U.S. farmers of abandonment of U.S. farm price supports is estimated to be a reduction of $11 billion in real income (Gardner 1985). This was about half of U.S. annual average net farm income in 1983-1985, but

Table 1.2. Redistributional effects of U.S. farm policies[a]

Commodity	U.S. Producers	consumers and tax payers	Total U.S.	Non-U.S.
		Billion Dollars		
Feed Grains	4.3	-6.5	-2.2	-0.6
Wheat	3.2	-3.8	-0.6	-0.7
Rice	0.6	-0.8	-0.2	-0.1
Cotton	1.4	-1.7	0.3	-0.2
Sugar	1.8	-2.9	-1.1	0.4
Dairy	1.7	-2.5	-0.8	n.e[b]
Tobacco	0.6	-0.4	0.2	-0.3
Peanuts	0.1	-0.1	0.0	n.e[b]
Beef	0.5	-0.5	0.0	n.e[b]
Total	14.2	-19.2	-5.0	

[a]Gardner (1985).
[b]not estimated.

the estimate does not imply such a sharp decline over a ten or twenty year horizon. Long run elasticities for supply of non-land inputs owned by farmers are high enough that the returns to them over the long run are essentially determined by returns in the much larger nonfarm sector.

Unfortunately, Gardner's calculations do not include a nonfarm sector or sufficient detail on input use to permit measurement of these effects. Thus, according to Gardner (1985), the effects of U.S policy liberalization would be a substantial short-term farm income loss and asset-value write-down. In long-run, the effects are argued to be not as severe. Admittedly, however, these results are conjectural. Also, results are calculated based upon elasticities from unrelated econometric work on commodity market and program effects. These elasticities are not from a consistent framework. In addition, the estimates are based on single-market supply and demand characteristics for the most part, although a few elasticities are supposedly "chosen" to incorporate total adjustments in a rudimentary form. But these estimates are partial in nature and do not incorporate the full effects.

Problem

Until recently, estimates of the cost and economic effects of agricultural policies have been conducted largely with partial equilibrium models. Gardner (1985) and Schmitz and Chambers (1986) are two such studies. These partial equilibrium analyses ignore the linkages among markets in the agricultural sector and of the agricultural sector to the remainder of the economy; important among these being the interactions between product and input markets. The importance of these economic linkages is now well recognized (Fischer et al. 1988, Robinson and Roland-Holst 1988, and Aradhyula et al. 1988).

Early work by Fox and Norcross (1952), and Schuh (1974) has led other studies on interactions between agricultural production, income and traditional features of macroeconomic policy (Shei 1978, Chambers and Just 1982). These and other studies have established linkages between agriculture and the rest of the economy and showed that there are large leakages out of and into agriculture, primarily via factor markets. Also, when there is an economy wide exogenous shock, as for tax or trade policy reform, the partial equilibrium approximations will be inadequate, particularly if agriculture is differentially affected (Hertel, 1986).

Of course, even if the general equilibrium feedback effects are not large, the more comprehensive framework can still play an important role by tying the pieces of policy analysis together in a theoretically consistent framework. An important implication of these more recent studies is that when analyzing the effects of agricultural policies on crop and livestock production, factor markets must also be considered simultaneously.

Realizing that the important linkages between agriculture and the rest of the economy are primarily through the factor markets, Adelman and Robinson (1986) used a social accounting matrix (SAM) to analyze exogenous shocks for agriculture. They constructed a SAM for the U.S. for the year 1982. The SAM describes the circular flow of money and goods in an economy. Using this SAM they derived multipliers, in much the same way they are derived in a traditional input-output framework. They found that leakages out of agriculture due to purchased inputs are large and that most of the value added in food production occurs between the farm gate and the consumer. These SAM results support a general equilibrium approach which emphasizes the simultaneous study of agricultural output and factor markets for evaluating farm policies. Yet, while the behavioral specification in the SAM multiplier analysis emphasizes important linkages in the economy, it is too simple for much policy analysis - the SAM, however, forms a good foundation for the more general models known as computable general equilibrium (CGE) models.

Hertel and Tsigas (1987) have expanded the work of Adelman and Robinson (1986). Using a general equilibrium model, they analyzed the economy-wide implications of a variety of different approaches to agricultural supply control that have surfaced in the recent U.S. farm policy debate. This is one of the few studies of agricultural policy in the U.S. using a general equilibrium framework. Based on 1984 policy wedges, they found acreage restrictions result in large increases in "excess burden" and domestic welfare losses. However their study was limited in that the elasticities are not econometrically estimated. Most of the elasticities used were accumulated from different studies. Also, the factor market, which is the key in general equilibrium models, was not adequately modeled. Like many other CGE studies, Hertel and Tsigas calibrated for the required general equilibrium parameters instead of using to econometric estimation. This facile practice of calibration, in addition, precludes the researcher from using more flexible functional forms in representing the structure of economic system. Other applied general equilibrium models that explored U.S. agricultural policies include the basic linked system (Fischer et al. 1988, and Frohberg et al. 1988), COMGEM (Hughes and Penson 1980), and Tyers (1985).

Production modules, comprising of output supply and input demand functions, form a key component of applied general equilibrium models. Several important gains have been made in estimating theoretically more sound output supply and input demand equations. Examples of these studies include Sidhu and Baanante (1981), McKay et al. (1983), Shumway (1983), Lopez (1984), Ball (1988), and Shumway and Alexander (1988). These studies clearly establish the usefulness of dual framework in estimating supply response. Notable among these studies are Shumway (1983), and Shumway and Alexander (1988). These studies have illustrated that for a multioutput firm, the profit function approach has several advantages over the cost function approach such as avoiding simultaneous equation bias. Crop supply and input demand functions for the U.S. agriculture have been successfully estimated in a theoretically more consistent framework.

However even these production module studies do not fully reflect commodity polices. In these studies, reduced form representations of policy variables are used in the supply equations. For example in Shumway and Alexander (1988), government commodity policies are captured by including target prices and diversion payments in the profit function. de Gorter and Paddock (1985) convincingly argue that such representations of policy are not satisfactory especially when the model is intended for policy analysis and exploring technical production relations (as opposed to forecasting).

Objectives

This study constructs a crop sector model for the U.S. comprising of crop output supply and input demand equations. The supply module explicitly incorporates key agricultural commodity policy instruments; loan rates, target prices, set-aside requirements and diversion payments. And this is accomplished in a structural framework. A theoretical model directly incorporating these policy variables in crop producer decision process is developed. That is, policy instruments are directly incorporated into the model in a structural framework, extending the work of de Gorter and Paddock (1985). Resulting expressions are estimated using a profit function in a dual framework for the U.S. crops sector.

In the functional specification and estimation of the model, the theoretical restrictions imposed by profit maximization and the technical response relations assumed are maintained. This makes the model consistent with a general equilibrium framework for the agricultural sector. Thus, flexible functional forms and a structural representation of commodity policies are combined in the study. The specific objectives of the study are:

1. To develop a theoretical model of the producer decisions on participation in voluntary commodity programs,
2. To structurally incorporate the governmental program variables in output supply and input demand equations estimated in a dual framework,
3. To estimate crop supply and input demand equations for the U.S. crop sector, and
4. To evaluate and assess the implications from the empirical findings using the structural policy representation.

Organization of the Study

The study is organized into eight chapters. Chapter I discusses the problem setting and the objectives of the study. Chapter II reviews and discusses various issues involved in the estimation of output supply and input demand equations and how policy variables are structurally incorporated. In Chapter III, a stylized theoretical model of the producer's decision is developed, incorporating the relevant features of the agricultural commodity policy. Chapter IV outlines how policy parameters are incorporated structurally in the empirical model. In Chapter V, estimation procedure is outlined. Data used in the estimation are also described in this Chapter. In Chapter VI, empirical results are presented, appraised and interpreted. Results of simulations that are possible given the elaborated policy structure are presented in Chapter VII. Finally, Chapter VIII contains a summary of the results in the study, an assessment of the findings and recommendations for future research.

CHAPTER II. POLICY STRUCTURE OUTPUT SUPPLY AND INPUT DEMAND

Commodity supply models are prominent in the applied agricultural economics literature. Supply relations have been estimated for a multitude of commodities and geographic locations (Askari and Cummings 1977). The purposes of such estimation are highly varied and include the search for basic knowledge of production relationships, policy inference and forecasting. The focus in this study is the first two of these objectives. This chapter reviews issues involved in the estimation of commodity supply and input demand equations followed by a discussion of policy variables treated in these models.

Commodity supply and input demand analysis in the U.S. agricultural has been carried out both in a single market framework and multi-market framework. Single product analysis (see for example, Houck and Ryan 1972, Morzuch et al. 1980, and Burt and Worthington 1988) examines the product supply in isolation and generally incorporates a greater institutional detail. Multi-market models of applied production analysis permit the interactions of several products. Examples of such studies applied to the crop sector of U.S. agriculture include Arzac and Wilkinson (1979), Gadson et al. (1982), Westcott and Hull (1985), Taylor (1987a, 1987b), Food and Agricultural Policy Research Institute (1987a, 1987b, 1988), and Johnson et al. (1988). The multi-market studies incorporate important interaction among crops. The functional form chosen in these models is mostly linear and the choice of explanatory variables is guided but not completely derived from the theory. Factor market effects are often omitted in these studies. The advantage of these parsimonious models is their ease of estimation and operation. Specification of equations is carried out without a rigorous foundation of the theory of the firm. The problem is that it is desirable to have models with a rigorous theoretical base. This would increase the confidence in the results.

Attention in this chapter is limited to studies which adhere more closely to the theoretical foundations of the theory of the firm. As desired, such studies typically simultaneously consider both the product supply and input demand together. The approach has been made more feasible by developments in duality theory and computational or estimation methods.

Duality

With competitive behavior and regular technology, there is a one-to-one correspondence between the production technology and the dual profit function (Chambers 1988). The technology characteristics can be examined directly using the primal approach or indirectly by a dual formulation. The product supply and input demand relationships to be developed, can be identified using either approach. The choice of approach is in large conditioned by data availability.

Also, it is often easier to compute product supply and input demand relationships using the dual, since simultaneous solution of the first order equations for profit maximization is unnecessary. Also, the dual formulation does not require output specific input use (Shumway 1983, Lopez 1984). Aggregate input use is sufficient for applying the dual approach, whereas in primal approach, data on output specific input use are necessary for estimation. This difference in data requirements is an especially important advantage because, in the U.S., data on crop specific input use are generally not available at a market level.

There are of course advantages of using a profit function approach in estimating multioutput production relations over the transformation, cost and revenue function approaches. In the profit function approach, no endogenous variables (output or input levels) are included as explanatory variables in the model to be estimated. Thus, the profit function approach circumvents the inconsistencies in the econometric estimation due to simultaneous equations bias (Lopez 1984). Because of the availability of data and it is also possible to recover all econometrically relevant information on the technology from the estimated profit function, a dual approach is applied in the present study.

At the time producer makes input and output decisions, output prices are not known. Previous studies have shown (Sandmo 1971, Aradhyula 1988) that when prices are not known ex ante, the risk neutral producer behaves as if prices are known with certainty and equal to the expected value. Hence, a profit function for a certainty case is equivalent to the expected profit function for a risk neutral producer.

However, the assumption of risk-averse behavior might be more desirable. Though theoretically more appealing, several problems exist in empirically implementing the assumption of risk-averse behavior. Two common approaches to incorporate producer's risk-avoiding behavior are (1) specifying a direct functional form for the utility function and production function, and (2) approximating the risk premium with a finite number of terms (Holt 1987). However, these two approaches have the same disadvantages as the primal approach under risk-neutrality.

A more appealing approach to incorporate risk-avoiding behavior in output supply equations would be to use an indirect specification of the expected utility function. This is much like using a profit function under certainty. More recently economists have begun to examine the implications of duality theory for specifying empirically tractable risk-responsive supply and input demand functions (Blair and Lusky 1977, Pope 1980, and Hallam et al. 1982).

Although duality approach may prove useful in incorporating risk-averse producer behavior, it presently remains at an elementary stage from the standpoint of practical application. The development of this approach is currently in the beginning stages. Additional basic research will be required before the duality approach will be useful as a tool for applied analysis of decisions under uncertainty (Holt 1987). In light of the state of present of theoretical developments, risk-neutral behavior is assumed in this study. This ensures that an expected profit function (i.e., profit function with expected prices, since profit is linear in prices) can be used to arrive at the output supply and input demand equations.

Many firms produce several commodities and others have this alternative. Thus, production decisions about one commodity are likely to be associated with production decisions about others. It is important to examine the extent of production interrelationships in order to understand more accurately the effects of policy changes and shifts in economic conditions. Thus jointness in agricultural production is important for assessing adequately the production effects of price and policy changes. Several studies such as Shumway (1983), Lopez (1984), Shumway and Alexander (1988) have shown the value of using a multioutput-multiinput framework in U.S. agriculture.

Profit Function

Consider the production decision for a multiproduct firm with m outputs, n variable inputs, and k fixed inputs and exogenous variables. Then the variable or restricted profit function, here after the profit function, can be expressed as:

$$(2.1) \qquad \pi(P,R,Z) = \max_{Y,X} \{P'Y - R'X;\ (Y,X,Z) \in T\}$$

where

π is variable profit (i.e., gross returns less variable costs),

T is the firm's production possibility set,

P is a m x 1 vector of output prices,

R is a n x 1 vector of input prices,

Z is a k x 1 vector of fixed inputs,

Y is a m x 1 vector of outputs $y_1, \ldots, y_m$, and

X is a n x 1 vector of variable inputs, $x_1, \ldots, x_n$.

Given profit maximization, the producer's problem is to choose the quantity of each output produced (y_i s) and the quantity of each variable input employed (x_i s). Thus, the profit function represents the maximum attainable profits, given the production technology and output and input prices. The profit function has the following properties (Lau 1978, Varian 1984, and Chambers 1988):

(2.2.1) $\pi(P,R,Z) \geq 0$ for all $P >> 0$: The profit function is a non-negative real valued function for all positive prices and any Z.

(2.2.2) $\pi(\lambda P,\lambda R,Z) = \lambda\pi(P,R,Z)$ for all $\lambda > 0$: The profit function is homogeneous of degree one in prices.

(2.2.3) Profit function is convex and continuous in P and R for every fixed Z.

(2.2.4) If $P \geq P^1$, $\pi(P,R,Z) \geq \pi(P^1,R,Z)$: The profit function is non-decreasing in output prices.

(2.2.5) If $R \geq R^1$, $\pi(P,R,Z) \leq \pi(P,R^1,Z)$: The profit function is non-increasing in input prices.

(2.2.6) The profit function is differentiable, only if there exists a unique profit maximizing supply or input.

If the profit function is differentiable then:

(2.3) $\partial\pi(\cdot)/\partial p_i = y_i(P,R,Z) \quad i = 1, 2, \ldots, m,$ and

(2.4) $\partial\pi(\cdot)/\partial r_i = -x_i(P,R,Z) \quad i = 1, 2, \ldots, n.$

This later set of properties is referred to as Hotelling's lemma. Equations (2.3) and (2.4) imply that output supply and input demand equations can be directly derived as the partial derivatives of the profit function with respect to output and input prices, respectively. It is this property that makes profit function approach appealing for empirical work.

Properties (2.2.3) and (2.2.6) yield two additional useful results. First, they imply that the matrix of second order derivatives of $\pi(P,R,Z)$ with respect to P and R given in (2.5), is positive semi definite,

$$(2.5) \qquad H = \begin{bmatrix} \partial^2\pi(\cdot)/\partial p_i\partial p_j & \partial^2\pi(\cdot)/\partial p_i\partial r_j \\ \partial^2\pi(\cdot)/\partial r_j\partial p_i & \partial^2\pi(\cdot)/\partial r_i\partial r_j \end{bmatrix}$$

In the empirical work, convexity of a profit function is verified (imposed) by checking (imposing) the positive definiteness of this matrix. Second, by Young's theorem in calculus, cross partial derivatives as specified in (2.6) must be equal:

$$\begin{aligned} &\partial^2\pi(\cdot)/\partial p_i\partial p_j = \partial y_i(\cdot)/\partial p_j = \partial y_j(\cdot)/\partial p_i = \partial^2\pi(\cdot)/\partial p_j\partial p_i, \\ (2.6) \quad &-\partial^2\pi(\cdot)/\partial r_i\partial r_j = \partial x_i(\cdot)/\partial r_j = \partial x_j(\cdot)/\partial r_i = -\partial^2\pi(\cdot)/\partial r_j\partial r_i, \text{ and} \\ &\partial^2\pi(\cdot)/\partial p_i\partial r_j = \partial y_i(\cdot)/\partial r_j = -\partial x_j(\cdot)/\partial p_i = \partial^2\pi(\cdot)/\partial r_j\partial p_i \end{aligned}$$

Equations in (2.6) are generally referred to as symmetry restrictions. They insure that the matrix H is symmetric.

To ensure that there is a duality with a corresponding production possibility set or transformation function, the profit function must satisfy the properties (2.2) to (2.6). Therefore it is imperative to verify that an empirically estimated profit function satisfies these properties. In the present study, the estimated profit function maintains all the theoretical restrictions in equations (2.2) through (2.6).

Aggregation

One of the most unattractive realities researchers face is that data generated and collected on a regular basis often do not confirm to the data or variables required by the theory. The preceding exposition on profit function and the implied product supply and input demand equations is based on a firm-level theory. However, researchers do not always have access to firm level data that enable them to characterize satisfactorily the technology for a particular firm. Often, as in the present case, data are available only at a relatively high degree of aggregation, and the researcher is reduced to estimating industry functions (or at best, representative firm) on the basis of either cross-sectional or time series data. Thus, theoretically derived firm-level functions have to be translated into market-level functions.

This use of market level data involves aggregation over firms. The transition from the firm level behavior to the analysis of industry level function is termed the "aggregation problem." The problem is similar in consumer theory where individual Marshallian demand functions are to be translated to market demand functions. The issues involved are, what functional forms for market functions are consistent with firm-level theory, what restrictions to be placed on firm-level functions to ensure they are consistent with the rules of aggregation. For a discussion of these and related topics see Green 1964, Gorman 1968, Deaton and Muellbauer 1980, Daal and Merkies 1984, Blackorby and Schworm 1988, Chambers 1988, and Pope and Chambers 1988.

When all firms face the same output and input prices and there are no fixed variables, then the aggregation problem does not impose restrictions on firm-level or market-level functions. For example, consider there are L number of firms. Then the market level profit function is given by:

(2.7) $\Pi(P,R) = \sum_{k=1}^{L} \pi_k(P,R)$

Applying Hotelling's lemma we get:

(2.7.1) $\partial\Pi(\cdot)/\partial p_i = \sum_{k=1}^{L} \pi_k(P,R)/\partial p_i = \sum_{k=1}^{L} y_{ik}(P,R) = Y_i(P,R) \quad i = 1, 2, \ldots, m,$ and

(2.7.2) $\partial\Pi(\cdot)/\partial r_j = \sum_{k=1}^{L} \pi_k(P,R)/\partial r_j = \sum_{k=1}^{L} -x_{jk}(P,R) = -X_j(P,R) \quad j = 1, 2, \ldots, n.$

This aggregation rule is frequently invoked in empirical studies. But the presence of firm specific variables (For example, fixed inputs, and firm specific prices) impose some restrictions on the functional forms of both aggregate and firm-level profit functions. These are discussed in Gorman 1968, Blackorby and Schworm 1982, Chambers 1988, and Pope and Chambers 1988. Relevant results are summarized in Table 2.1. As explained in Chapter IV, results of both linear and non-linear aggregation rules given in Table 2.1 are invoked in the present analysis.

Flexible Functional Forms

In a parametric analysis (econometric or programming), a first step is an assumption on the structure of technology. Traditionally this has meant specification of a production function involving very few parameters. However, advances in computer technology have made it practical to handle much more complicated functional forms. With this enhanced ability has come an increased desire for generality in representing technology in applied work. This desire, largely spurred by the work of Diewert (1971), has led to much interest in what are known as flexible functional forms (FFFs).

In specifying functional forms for applied production analysis as in the present case, it is desirable to have estimable relationships that place relatively few prior restrictions on technology. Estimability typically implies a choice of form, and once the form is parameterized in accordance with the underlying economic theory (homogeneity, monotonicity, convexity, etc.), duality results guarantee the existence of a unique dual function.

An algebraic functional form for a profit function $\pi(P,R;\theta)$ is said to be flexible if at any given set of non-negative output and input prices (P and R), the parameter vector θ can be chosen so that the profit function, the implied output supply and input demand functions, and their own and cross price elasticities are capable of assuming

Table 2.1. Summary of Aggregation Results[a]

Problem:

Finding market level function g(w,b), such that,

$$g(w,b) = \sum_{i=1}^{L} g_i(w_i,b)$$

$$w = w(w_1,w_2,...,w_L)$$

where, L = number of firms

Results:

Linear w ($w = \sum_{i=1}^{L} w_i$):

$$g(w,b) = v(b) \cdot w + m(b)$$

$$g_i(w_i,b) = v(b) \cdot w_i + m_i(b)$$

$$m(b) = \sum_{i=1}^{L} m_i(b)$$

Nonlinear w:

$$g(w,b) = v(b) \cdot h(w) + m(b)$$

$$g_i(w_i,b) = v(b) \cdot h_i(w_i) + m_i(b)$$

$$h(w) = \sum_{i=1}^{L} h_i(w_i)$$

$$m(b) = \sum_{i=1}^{L} m_i(b)$$

---

[a]Chambers, 1988.

arbitrary values at the given set of prices subject only to the theoretical consistency (Chambers 1988). However, as Blackorby, Primont and Russel (1977), and Lopez (1985) point out flexible functional forms nevertheless impose some a priori restrictions, and all flexible functional forms are not equally suitable as dual representations of technology

A primary goal of applied production analysis is empirical measurement of the economically relevant information that exhaustively characterizes the behavior of economic agents. For smooth technologies, this includes the value of the function (e.g., the level of production, profit), the gradient of the function (e.g., marginal productivities) and the Hessian (e.g., the matrix of elasticities). In other words, for any primal or dual technology with n netputs (outputs and negative inputs), there are $\frac{1}{2}(n+1)(n+2)$ economically relevant effects. Therefore, in choosing a functional form, one rich enough in parameters to portray all of these effects should be the employed.

A functional form is flexible if it does not impose a priori values to any of these $\frac{1}{2}(n+1)(n+2)$ coefficients. The flexible form lets the data determine these effects. Thus, a functional form in n variables should have at least $\frac{1}{2}(n+1)(n+2)$ parameters to be a FFF. This is best demonstrated by a counter example. Consider, a Cobb-Douglas production function in two inputs L, and K; $y = aL^{\alpha}K^{\beta}$ with three parameters, where as there are $\frac{1}{2}(3+1)(3+2) = 10$ distinct economic effects to be captured. Obviously, the three parameters in Cobb-Douglas functional form cannot capture the 10 different effects. Thus Cobb-Douglas is not a FFF. A FFF on the other hand would have at least 10 parameters. The flexible functional forms are designed to provide local, second-order approximations to arbitrary functional forms. For a discussion on flexibility criteria and other definitions see Diewert 1974, Blackorby et al. (1977, 1978), and Barnett (1983b, 1985).

The common examples of FFFs are Diewert's (1971) generalized Leontief, the translog (Christensen et al. 1973) and normalized quadratic (Lau 1978). Recent additions include generalized McFadden (Diewert and Wales 1987), Barnett's (1983a) miniflex Laurent, and Gallant's (1981, 1982, 1984) Fourier flexible forms. For a review and discussion of alternative functional forms and choice among them see Rossi (1985), Griffen et al. (1987), Thompson (1988), and Baffes and Vasavada (1989).

Normalized Quadratic Profit Function

In the present study, a flexible functional form is used to represent the optimizing behavior of producers. Specifically, a normalized quadratic functional form is used to represent variable profit function. The normalized quadratic functional form represents a second order Taylor series approximation to the true and unknown profit function. For a technology with m outputs, n variable inputs (with m+n=q), and K fixed inputs or exogenous variables, market-level normalized (normalized by EP_q) quadratic profit function is given by:

$$(2.8) \quad \Pi^*(P,Z) = a_0 + \sum_{i=1}^{q-1} a_i\, EP_i + \sum_{i=1}^{q-1} \sum_{j=1}^{q-1} b_{ij}\, EP_i\, EP_j + \sum_{k=1}^{K} c_k\, Z_k + \sum_{k=1}^{K} \sum_{l=1}^{K} d_{kl}\, Z_k\, Z_l + \sum_{i=1}^{q-1} \sum_{k=1}^{K} f_{ik}\, EP_i\, Z_k$$

where,

Π^* is profit divided by the price of nth input (that is, normalized profit),

EP_i is expected price of ith netput,

Z_k is quantity of kth fixed input or exogenous variable, and

a_0, a_i, b_{ij}, c_k, d_{kl}, and f_{ik} are parameters to be estimated. Note that the vector P now contains prices of both outputs and inputs. In the present analysis there are thirteen crops (m=13), four variable inputs (n=4), one fixed input and three other exogenous variables (K=4). By Hotelling's lemma, the first derivatives of a normalized profit function with respect to normalized output prices and normalized variable input prices are the output supply and (negative of) variable input demand equations (see equations 2.3 and 2.4)

Except for the numeraire input, all product supply and negative input demand equations derived from the normalized quadratic profit function are linear in normalized product and variable input prices and fixed input quantities:

(2.9a) $Y_i = a_i + \sum_{j=1}^{q-1} b_{ij}\ EP_j + \sum_{k=1}^{K} f_{ik}\ Z_k \quad i = 1, 2, ..., m$

(2.9b) $-X_i = a_i + \sum_{j=1}^{q-1} b_{ij}\ EP_j + \sum_{k=1}^{K} f_{ik}\ Z_k \quad j = 1, 2, ..., n-1$

(2.9c) $-X_n = a_0 - \frac{1}{2}\sum_{i=1}^{q-1} \sum_{j=1}^{q-1} EP_i\ EP_j + \sum_{i=1}^{K} c_k\ Z_k + \sum_{k=1}^{K} \sum_{l=1}^{K} d_{kl}\ Z_k\ Z_l$

Note that Z variables in equations (2.8) and (2.9) represent fixed inputs (such as capital stock) and exogenous variables (such as time for technology). For a fixed input Z_j which represents an aggregate input level (for example, capital stock in the U.S. agriculture), consistent aggregation across firms requires that $\Pi^*(P,Z)$ be affine in Z_j i.e., $\partial^2\Pi^*(P,Z)/\partial Z_j Z_j = d_{jj} = 0$ (see Table 2.1). In such cases d_{jj} is set equal to zero a priori in the estimation.

Normalized quadratic profit function has several advantages over other flexible functional forms such as translog or generalized Leontief. For a normalized quadratic profit function, the implied output supply and input demand equations are linear in variables and parameters (only the numeraire equation is nonlinear). This linearity is convenient in the estimation. More importantly, the matrix of second derivatives of a normalized quadratic profit function with respect to prices is constant. This constant matrix of second order derivatives has two desirable implications. First, this would make it easy to check the convexity of profit function in prices - by simply checking for the positive semi-definiteness of the matrix. Second, a constant matrix of second derivatives indicate that local convexity implies global convexity.

Thus, with a normalized profit function, one could impose global convexity restrictions by simply restricting the matrix of constant second derivatives to be positive semi-definite. Since the matrix of second derivatives is not constant, imposing global convexity is not so convenient with other flexible functional forms such as translog and generalized Leontief. Further more, previous studies have shown that a normalized quadratic function can be successfully used to represent the complex agricultural production technologies (Shumway 1983, Shumway et al. 1987, Moschini 1988a, and Shumway and Alexander 1988). In the present study a normalized quadratic functional form was used for the profit function and implied supply and demand equations (2.9) were estimated simultaneously.

Policy Structure

The estimation of the agricultural supply response to changing government commodity programs has been problematic due to the frequent adjustments in the commodity programs, as well as changes in underlying payment structures and supply reduction parameters (de Gorter and Paddock 1985). It is most common to incorporate the influence of commodity programs in reduced form framework, with variables like the effective support payment and diversion payment as explanatory variables in planted acres equations (Houck and Ryan 1972, Lee and Helmberger 1985). Even theoretically more elegant studies such as Ray (1982), Shumway (1983), Lopez (1984), Chang and Shumway (1988), and Shumway and Alexander (1988) have not used complete specification when incorporating policy variables. Policy representations in these studies are rudimentary.

Due to the simplicity in introducing policy, in many of the studies that have reduced form representations of policy parameters, the objective according to which farmers make productions decisions is not explicitly and fully specified. Even in those where an objective function is specified, explicit introduction of policy parameters into the objective function is neglected. A structural representation, on the other hand, completely specifies an objective function including the policy structure conditioning producer behavior . Relevant policy variables are embedded explicitly in this decision making process of the individual producer.

This discussion of policy raises the famous Lucas critique (Lucas 1981, page 126), "... given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models.... It implies that comparisons of the effects of alternative policy rules using current macroeconometric models are invalid regardless of the performance of these models over the sample period..."

Reduced form representations of policy are more susceptible to Lucas criticism than a structural representations. Narayana and Parikh (1988) contend that for small changes in policy, the parameters of structural models are likely to be more stable than those of the reduced form models. Models with more structure are relatively more robust in the sense that their parameters can be expected to hold under policy simulations outside the observed range of data. However, in light of the Lucas critique, the temptation of evaluating big changes in policy should be resisted. That is, caution should be deployed in the use of a model for the policy analysis even if the model has a structural representation. Of course, even the most structural representation of policy is in fact an approximation.

de Gorter and Paddock (1985) point out, that reduced form representations of policy in the U.S. crop sector suffer from one additional problem. The composite variables (such as effective support price in Houck and Ryan 1972, and Shumway and Alexander 1988) used to represent policy in reduced form, ignore the voluntary nature of the commodity programs, and impose questionable restrictions on the effects of changing policy parameters. Specifically, these studies fail to develop a consistent analytical framework that distinguishes the factors affecting a producer decision to participate in voluntary programs from factors affecting the choice by participant and non-participants on the level of production. But more satisfactory models of supply response for the purposes of forecasting, econometric policy evaluation and economic welfare analysis require a more complete identification of the structural parameters governing production and price determination. These ideas lead de Gorter and Paddock (1985) to advance a corn supply response model that explicitly accounted for the discrete program participation choice, as well as the continuous planting decision.

Summary

In this study policy variables are incorporated in a structural framework, following de Gorter and Paddock (1985). Their conceptual and methodological frameworks are extended. The participation rate in the voluntary commodity programs is endogenized. This structural implementation of these policy variables in a theoretically consistent framework represents a contribution to improved agricultural policy evaluation.

CHAPTER III. THEORETICAL CROPS COMPONENT SPECIFICATION

This chapter provides a brief review of key policy instruments in the U.S. commodity program. This is followed by a presentation of a stylized theoretical model of producers decision process regarding participation in the voluntary commodity programs. Relevant policy variables are embedded explicitly in this decision making process of the individual producer.

Policy Instruments and U.S. Farm Programs

Present U.S. farm policy has evolved over the past 50 years. Legislation authorizing programs in the U.S. to support farm prices and income, or to curtail planted acreage generally provides a range within which programs can be administered. In practice, program provisions are specified for one year at a time with considerations given to expected supply, demand, and price relationships. The structure of policy differs from commodity to commodity. For a list of the existing commodity programs see Table 1.1. Different policy instruments are used in administering these farm programs. Selected instruments for U.S. commodity programs are reviewed in this section as a basis for the present analysis. This review of program operations, which is neither exhaustive not inclusive, will stress the key policy instruments that have played an important role in postwar production decisions of crop producers. More complete details of the U.S. crop programs can be found in Brandow (1977), Cochrane and Ryan (1976), Lee and Helmberger (1982), Paarlberg (1980), USDA (1984), and Glaser (1986).

Market price supports

All of the major supported commodities have a form of market price floor. Generally, Commodity Credit Corporation (CCC), a federal institution, removes the commodities from market at designated support price levels. For most of the supported commodities, including the grains, the price floor is determined by the "loan rate", a price paid to farmers who place grain in storage near harvest time. The farmer has the option of repaying the loan and selling the commodity on the market, or turning the commodity over to the CCC in payment for the loan plus interest. This option along with the voluntary nature of the programs results in the CCC acquiring as much commodity as it is necessary to maintain the market price near the loan rate. Because no significant export taxes, subsidies or quantitative export restrictions exist, the loan rates have historically supported commodity prices in the world trade (Gardner, 1985)[1].

Target prices

This legislated price provides price insurance to farmers by making payments to farmers to supplement market receipts if the market price falls below the target price. The payments are roughly sufficient to guarantee producers the target price; "rough" because the payments are based on U.S. average prices and historical "base" yields, not on each producer's actual price and actual yield. These government transfers made to farmers are referred to as deficiency payments. The payment rate is per unit of output (bushel, pound or hundredweight depending on the crop) and is derived using the following formula:

deficiency payment = [target price - max(market price, loan rate)]•Base yield.

Of course, when market price exceeds the target price, there is no deficiency payment. Typically, farmers have to idle acreage to qualify for program participation and deficiency payments.

Acreage controls

Payments made to farmers for not growing crops were a mainstay of 1950s programs (the "Soil Bank") and evolved into the "set-asides" and voluntary paid diversions. Set-asides require farmers to idle a fraction, typically 10-20 percent, of an acreage base to qualify for target prices and CCC loans. "Base" acreage (or acreage allotments and later called "national program acreage") is predetermined for each producer using historical acreage. In several years, participating producers have had the option to receive diversion payments for idling additional acreage (up to a maximum). These voluntary paid diversion programs are essentially offers by the government to rent a farmer's land, which is then left idle. An important feature of these programs is their voluntary nature; the decision to participate in these programs is left to individual farmers.

Other instruments of farm policy include reserve stocks of commodities (example, farmer-owned reserve program for grains), export subsidies, disaster payments, subsidized credit and insurance, tax-shelter, etc. See Brandow (1977), Cochrane and Ryan (1976), Lee and Helmberger (1982), Paarlberg (1980), USDA (1984), and Glaser (1986) for details.

The Model Program

Consider a stylized voluntary government program which includes acreage reduction, an established base acreage, and a guaranteed support price for participating firms. The acreage restriction is represented by the set-aside parameter SET where, SET $\in [0, 1]$. The parameter SET is the portion of the base acreage, LB, which a participant must idle to comply with program provisions. Thus, SET is the share of the base acres idled, or the set-aside requirement. In other words, due to the set-aside acreage restriction, a participant using (planting) L units of land must control L/(1-SET) units of land[2]. The guaranteed minimum price that participants are eligible to receive is denoted by P_m. The set of program parameters in this stylized but structural policy model is then given by (P_m, SET)[3]. In the full development of the policy structure, a paid-diversion program is also included.

An important aspect of the government program structure is that participants are guaranteed a minimum price P_m for their production. If the market price is below P_m, the participant can, in essence, sell to the government and receive the minimum price. If the market price is above P_m, participants can sell at the higher free-market price. This feature of the government program alters the first moment of the price distribution, the expected price. Of course, the guaranteed minimum price also alters higher moments of the unknown farm price's distribution, although higher moments do not concern the risk neutral producer. In essence, the imposition of a minimum price truncates the distribution of possible price outcomes for program participants (Eeckhoudt and Hansen, 1980). This is illustrated in Figure 3.1.

If a new random variable PP (participant price) is defined such that:

$$(3.1) \quad PP = \begin{cases} P_m & \text{if } FP \leq P_m \\ FP & \text{if } FP \geq P_m \end{cases}$$

then the truncated cumulative probability density function, G(PP) is defined as:

$$(3.2) \quad G(PP) = \begin{cases} H(P_m) & \text{if } FP \geq P_m \\ H(FP) & \text{if } FP \leq P_m \end{cases}$$

and the expected price for the participant producers E[PP] can be expressed as:

$$(3.3) \quad E(PP) = EPP = H(P_m).P_m + \int_{P_m}^{\infty} FP\, h(FP)\, dp$$

where,

FP is random unknown farm price with E(FP) = ENP

h(FP) is subjective probability density function of FP,

H(FP) is subjective cumulative function of FP,

P_m is target or minimum guaranteed price to the program participants, and

PP is price received by the participants.

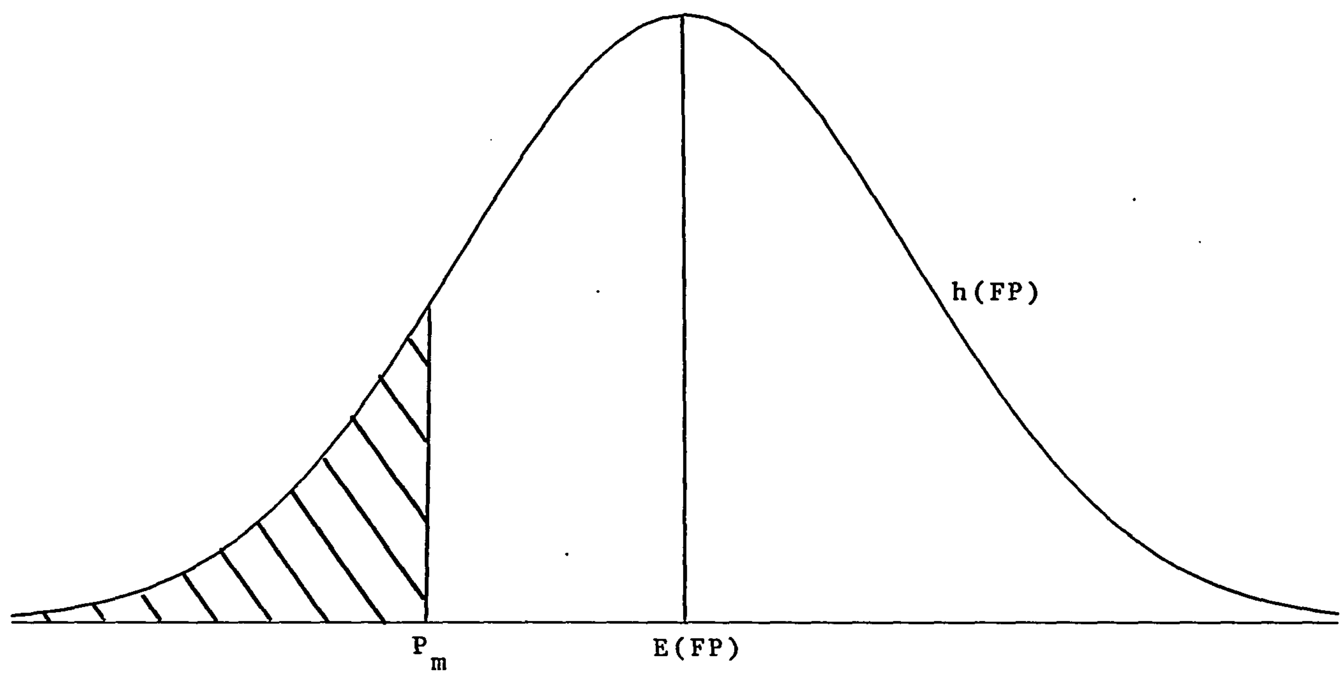


Figure 3.1. Truncation of a hypothetical probability distribution of price at the guaranteed minimum price P_m

The minimum price P_m is the truncation point for the original price distribution (see Figure 3.1). The probability $H(P_m)$ that price will fall below P_m is represented by the hatched area in Figure 3.1. The value $H(P_m)$ is assigned to the point P_m in the truncation process. The distribution for PP is referred to in statistical literature as a "mixed distribution" since it has both discrete and continuous components. Note that the expected price for the non-participant producer is simply the expected market price, denoted by ENP. Obviously,

(3.4) $\quad EPP = E(PP) > ENP = E(FP) \quad \text{if } H(P_m) > 0.$

Thus, the expected price for a participant is higher than for the non-participant. This is the incentive to participate in the commodity program. Of course, in return to this higher expected price, participants idle a proportion (SET) of their base acreage. Differentiating (3.3) with respect to P_m gives,

(3.5) $\quad dE(PP)/dP_m = H(P_m) > 0.$

Equation (3.5) shows that the expected price for participants E(PP), increases as P_m increases.

The Participation Decision

The producer decision model is developed to determine participation in commodity programs and input utilization. The basic features of voluntary commodity programs to be incorporated include price supports (direct payments from 1961 to 1977 and deficiency payments thereafter), which are conditional on an amount of the participating producers' base acreage being diverted (the set-aside).

An important feature of U.S. commodity programs is that they are voluntary. Supply response models for commodities subject to voluntary government programs must explicitly consider the discrete nature of the participation decision (Holt, 1987). One method of explicitly treating this decision problem is to use a microeconomic model of discrete/continuous choice in production (for example, Duncan, 1980; Hanenmann and Tsur, 1982; Just and Zilberman, 1983; Hall and Duncan, 1984). Although these models are primarily designed to handle disaggregated, firm-level data, de Gorter and Paddock (1985) have adopted this basic framework to analyze aggregate commodity program participation decisions.

To keep the analysis tractable, we begin with the following assumptions. Later, these assumptions will be relaxed and the problem re-examined. The firm produces one crop. The price of the output is unknown at the time input decisions are made. That is, the producers choose whether to participate in the government program or not before observing the final price. Also, the participant must choose input levels ex ante. This assumption is consistent with present day regulation of agricultural markets. The production process involves two inputs, land (L) and a composite non-land input (K).

We assume the producer is risk neutral. Although the assumption is restrictive, it simplifies the analysis. Also, there is evidence which supports the assumption that producers are profit maximizers (see, for example, Gardner and Chavas, 1979; Pope, 1981; Shumway and Alexander, 1988). Also, under risk-neutrality, translating theoretical model into empirical structure is relatively simple using an expected profit function. On the other hand, risk aversion would necessitate the inclusion of variance and other higher moments of the distribution of the unknown random prices.

Non-participant

The objective function for a firm that does not participant in the government program is:

(3.6) $\quad \text{Max } E(\pi) = ENP \cdot f(L, K) - r\,L - w\,K$

where,

$E(\pi)$ is the expected profits of the firm, ENP is the expected farm price,

$f(\cdot)$ is a twice differentiable production function,

L is the amount of land input used,

K is the amount of non-land input used, and

r is the rental price of land, and

w is the price of non-land input.

The choice variables in (3.6) are L and K. Note that ENP = E(FP). First order necessary and second order sufficient conditions for (3.6) are given by (3.7) and (3.8) respectively.

(3.7a) $ENP \cdot f_L(L, K) - r = 0$

(3.7b) $ENP \cdot f_K(L, K) - w = 0$

(3.8a) $f_{LL}(L, K) < 0$

(3.8b) $f_{KK}(L, K) < 0$

(3.8c) $|S| = f_{LL}(L, K) \cdot f_{KK}(L, K) - f_{LK}(L, K) \cdot f_{KL}(L, K) > 0$

If equations (3.8a), (3.8b), and (3.8c) hold, equations (3.7a) and (3.7b) can be solved for the optimal amounts land and non-land input (L^n and K^n) as functions of ENP, r and w:

(3.9a) $L^n = L^n(ENP, r, w)$, and

(3.9b) $K^n = K^n(ENP, r, w)$.

Equation (3.9) represent optimal input demands. The superscript n denotes the non-participant firm.

Substituting the L^n and K^n in (3.6) we obtain the optimal output y^n, and maximum expected profits π^n,

(3.10) $y^n = f(L^n(ENP, r, w), K^n(ENP, r, w))$

$= y^n(ENP, r, w)$, and

$$(3.11)\quad \pi^n = ENP \cdot f(L^n(ENP, r, w), K^n(ENP, r, w))$$
$$- r L^n(ENP, r, w) - w K^n(ENP, r, w)$$
$$= \pi^n(ENP, r, w).$$

Equation (3.11) corresponds to the indirect profit function of equation (2.1).

Participant

For the firm to comply with the regulations of the commodity program, i.e., for a program participant, the objective is :

$$(3.12)\quad \text{Max } E(\pi) = EPP \cdot f(L, K) - r\, L/(1-SET) - w\, K$$

where,

SET is the set-aside requirement, and

EPP is the expected price to the participant.

Other variables are as defined earlier. Note that $r/(1-SET)$ can be interpreted as the effective price of land for the participant. Thus, a participating producer has an higher expected output price (EPP > ENP) and a higher land input price ($r/(1-SET) > r$). The choice variables in (3.12), as in (3.6), are L and K.

The first order necessary and second order sufficient conditions for (3.12) are (3.13) and (3.14), respectively.

$$(3.13a)\quad EPP \cdot f_L(L, K) - r/(1-SET) = 0$$

$$(3.13b)\quad EPP \cdot f_K(L, K) - w = 0$$

$$(3.14a)\quad f_{LL}(L, K) < 0$$

$$(3.14b)\quad f_{KK}(L, K) < 0$$

$$(3.14c)\quad f_{LL}(L, K) \cdot f_{KK}(L, K) - f_{LK}(L, K) \cdot f_{KL}(L, K) > 0$$

Under the second order sufficient conditions in (3.14a), (3.14b), and (3.14c), equations (3.13a) and (3.13b) can be solved for the optimal amounts of land and non-land input (L^* and K^*) to yield:

(3.15a) $L^* = L^*(EPP, r/(1-SET), w)$, and

(3.15b) $K^* = K^*(EPP, r/(1-SET), w)$.

Equations (3.15) represent the optimal demands for land and non-land inputs, respectively, for the program participants. The superscript * is used to denote a participant producer. Substituting expressions for L^* and K^* in (3.12), yields the optimal output, y^* and maximum expected profit π, i.e.,

$$(3.16)\quad y^* = f(L^*(EPP, r/(1-SET), w), K^*(EPP, r/(1-SET), w))$$
$$= y^*(EPP, r/(1-SET), w), \text{ and}$$

$$(3.17)\quad \pi^* = EPP \cdot f(L^*(EPP, r/(1-SET), w), K^*(EPP, r/(1-SET), w))$$
$$- r\, L^*(EPP, r/(1-SET), w) - w\, K^*(EPP, r/(1-SET), w)$$
$$= \pi^*(EPP, r/(1-SET), w).$$

Note that EPP, the expected output price for the participant is a function of P_m (see equation (3.3)). Also, from the envelope theorem (Silberberg 1978, p 168), taking the partial derivative of the objective function with respect to EPP, the supply function is:

$$\partial\pi^*(EPP, r/(1-SET), w)/\partial EPP = y^*(EPP, r/(1-SET), w),$$

and hence,

$$\partial\pi^*(EPP, r/(1-SET), w)/\partial P_m = (\partial\pi^*(\cdot)/\partial EPP_m)\cdot(\partial EPP/\partial P_m)$$
$$= H(p_m)\cdot y^*(EPP, r/(1-SET), w).$$

The marginal rate of technical substitution of non-land input for land is defined by:

$$MRTS = (\partial f(\cdot)/\partial L)/(\partial f(\cdot)/\partial K) = f_K(\cdot)/f_L(\cdot).$$

From equation (3.13), the MRTS for a participant is:

$$MRTS^* = r/w(1-SET)$$

Likewise the MRTS for a non-participant is determined from equation (3.7) is:

$$MRTS^n = r/w.$$

Thus, for a given level of output MRTS* > $MRTS^n$ i.e., for a given level of output, participants use the non-land input more intensively. This is illustrated in Figure 3.2. In Figure 3.2 line C1 represents the factor price ratio of r/w(1-SET) for the participants while line C2 represents the relevant factor price ratio for the non-participant. Since 0 ≤ SET ≤ 1, C1 is steeper than C2, representing a higher "effective" rental price of land for participants. Curve y_0 represents an isoquant for the given level of output $y_0 = F(L, K)$. For this level of output, points 1 and 2 where C1 and C2 are tangent to y_0, represent optimal factor mix. Clearly, for this output y_0,

$$K_1/L_1 > K_2/L_2$$

This condition holds at any given level of y. However, in general, y* and y^n would be different and no inference could be drawn[4] on the relative magnitudes of K_1^*/L_1^* and K_2^n/L_2^n.

Participation

The producer will choose to participate in the commodity program iff $\pi^* \geq \pi^n$. Conversely, the producer will not participate in the commodity program if $\pi^* < \pi^n$. It might be noted that the participation decision differs from producer to producer based on available technology given by f(L, K), and the expectations as given by h(FP). In the present analysis, it is assumed that technology (and not price expectations) differ among firms. Comparative statics analysis yields the sensitivity of producer decisions to the government program parameters, SET and P_m as well as the underlying distribution h(FP).

First the effects of a change in target price are investigated. Note that a change in target price effects the program participant through a change in EPP, the expected price for the participant. Specifically, for a program participant, a change in target

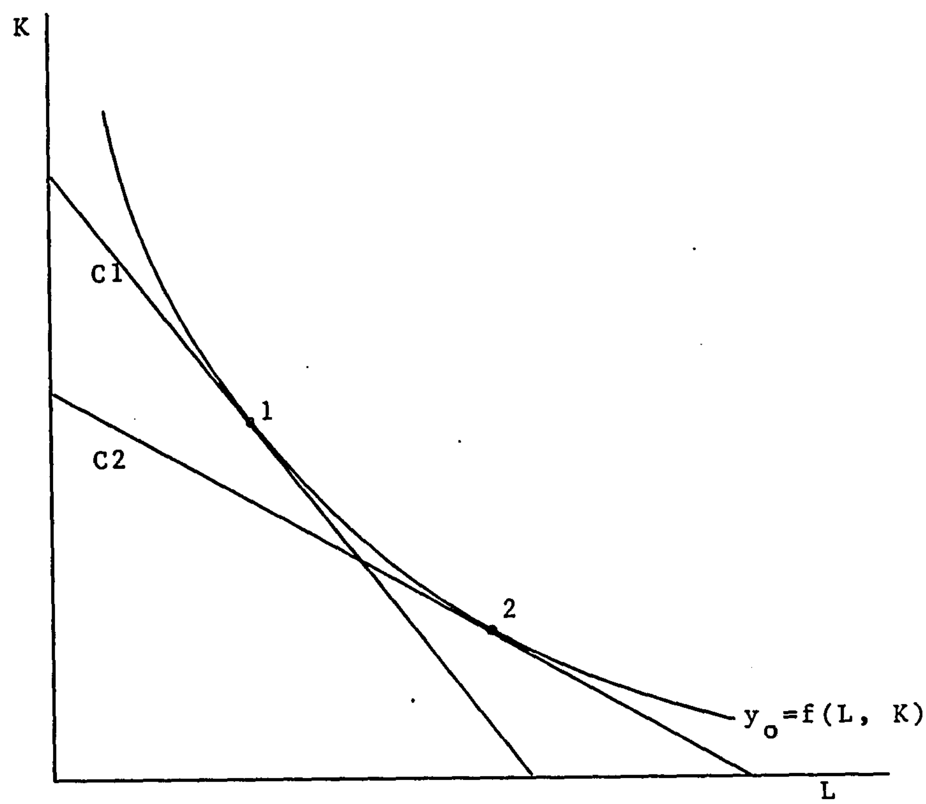


Figure 3.2. Factor intensities for participants and non-participants in a commodity program

price effects the optimal input use (and hence production) via the equation (3.5). Differentiating equation (3.13) with respect to EPP and rearranging, yields

(3.18a) $\partial L^*/\partial EPP = (1/EPP)\cdot[f_K(\cdot)\cdot f_{LK}(\cdot) - f_L(\cdot)\cdot f_{KK}(\cdot)]/|S|$, and

(3.18b) $\partial K^*/\partial EPP = (1/EPP)\cdot[f_L(\cdot)\cdot f_{LK}(\cdot) - f_K(\cdot)\cdot f_{LL}(\cdot)]/|S|$.

In general, no refutable implications emerge from these expressions per se, i.e., the signs of expressions in equations (3.18a) and (3.18b) can not be established (Silberberg 1978, page 113, and Beattie and Taylor 1985, pages 120-123).

Using $\partial EPP/\partial P_m$ from equation (3.5) we obtain,

(3.19a) $\partial L^*/\partial P_m = H(P_m)\cdot(1/EPP)\cdot[f_K(\cdot)\cdot f_{LK}(\cdot) - f_L(\cdot)\cdot f_{KK}(\cdot)]/|S|$, and

(3.19b) $\partial K^*/\partial P_m = H(P_m)\cdot(1/EPP)\cdot[f_L(\cdot)\cdot f_{LK}(\cdot) - f_K(\cdot)\cdot f_{LL}(\cdot)]/|S|$.

Again, as in the standard micro theory, the signs of expressions in equations (3.19) can not be established. An increase in the target price, P_m, can lead to an increase or a decrease in the use of either factor, since the sign of $f_{LK}(\cdot)$ is unknown. However, it can be shown that both $\partial L^*/\partial P_m$ and $\partial K^*/\partial P_m$ can not be negative simultaneously. That is, if target price increases then the use of at least one input must go up. This is because, an increase in target price will cause an increase in production for the program participant, and it is impossible, with positive marginal products, to produce more output with less of both factors.

To demonstrate $\partial y^*/\partial P_m > 0$, differentiate equation (3.16) with respect to P_m:

(3.20) $$\partial y^*/\partial P_m = (\partial EPP/\partial P_m)\cdot(\partial y^*/\partial EPP)$$
$$= H(P_m)\cdot(\partial y^*/\partial EPP) > 0.$$

The second term on the right hand side of equation (3.20) is positive, since supply curves are positively sloped (Silberberg 1978, pages 113-114)[5]. Thus, the supply function for a participant is positively sloped both in target price and expected price space.

Note that the first order necessary conditions for non-participant given in equation (3.7) do not contain the parameter, P_m. Thus, for a producer who chooses to be non-participant, target price has no effect on the optimal input use and level of production. Finally, we can investigate how a change in target price effects the participation decision itself.

Let $Z = \pi^* - \pi^n$. Then, a variable v, will not affect the participation decision iff $dZ/dv = 0$. If $dZ/dv > (<) 0$, then an increase in v would make the commodity program more (less) attractive. We now can make the following result:

Result 1:

> An increase (decrease) in target price will make participation in the commodity program more profitable and hence will not decrease (increase) the number of program participants.

Proof:

$\partial Z/\partial P_m = (\partial\pi^* - \partial\pi^n)/\partial P_m = \partial\pi^*(\cdot)/\partial P_m - \partial\pi^n(\cdot)/\partial P_m = y^* H(P_m) - 0 \geq 0$ QED.

A strict inequality is not used since it is possible that $H(P_m)$ is zero.

Thus, a change in the target price may well result in a change in the participation decision. Investigation of these effects of target prices on output (when the change in target price induces the producer to switch the participation decision) is complicated. The question is, what would happen to the level of production, if a producer moves from being a non-participant to a participant or vice versa? This is an important result because there is an ongoing debate on the effects of current farm programs on farm production (output).

The producer is indifferent between the participation in the commodity program, if $\pi^*(K^*, L^*) = \pi^n(K^n, L^n)$. Then, the effect of a change in P_m on the output when the change in P_m results in a switch in program decision, can be obtained by comparing y^* to y^n at the point, $\pi^*(K^*, L^*) = \pi^n(K^n, L^n)$. The sign of $(y^* - y^n)$ evaluated at $(\pi^* - \pi^n = 0)$ is, in general, indeterminate. This is illustrated in Figure 3.3.

In Figure 3.3, the supply curve of a non-participant producer is given by the horizontal line y^n. The supply curve of the same producer, if a participant, is the positively slopped curve y^*. For a program participant, note that profits at point G would be higher than at A. The objective is to generate a composite supply curve which has participation decisions embedded.

There exists a sufficiently low support price such that $\pi^*-\pi^n < 0$. Let D be such a point. Now suppose P_m increases. For small changes in P_m, the producer may remain as a non-participant. Then, as shown earlier, output y^n will not change. Hence, the producer will remain or stay on the horizontal line y^n. But as P_m increases, π^* will increase and at some P_m, π^* will equal π^n. At this point the producer will be indifferent between participation and non-participation. However, at this point y^* could be different from y^n. Any further increase in P_m will make the producer a participant. When the producer makes this jump, output can go up or go down. Thus, the composite supply curve could be discontinuous. It could drop as the policy makers perhaps hope. That is, the supply curve as a function of P_m, could be DEABCG or DEBCG or DEBFCG. However, the first derivative of supply curve with respect to the support price P_m, when it exists, is always positive.

Carrying-out a similar analysis for the set-aside parameter SET, we obtain:

(3.21) $\partial L^*/\partial SET\Big|_{\pi^*>\pi^n} = [f_{KK}(\cdot)r]/[EPP\cdot(1-SET)^2\cdot |S|] < 0,$

(3.22) $\partial K^*/\partial SET\Big|_{\pi^*>\pi^n} = -[f_{KL}(\cdot)r]/[EPP\cdot(1-SET)^2\cdot |S|]$, and

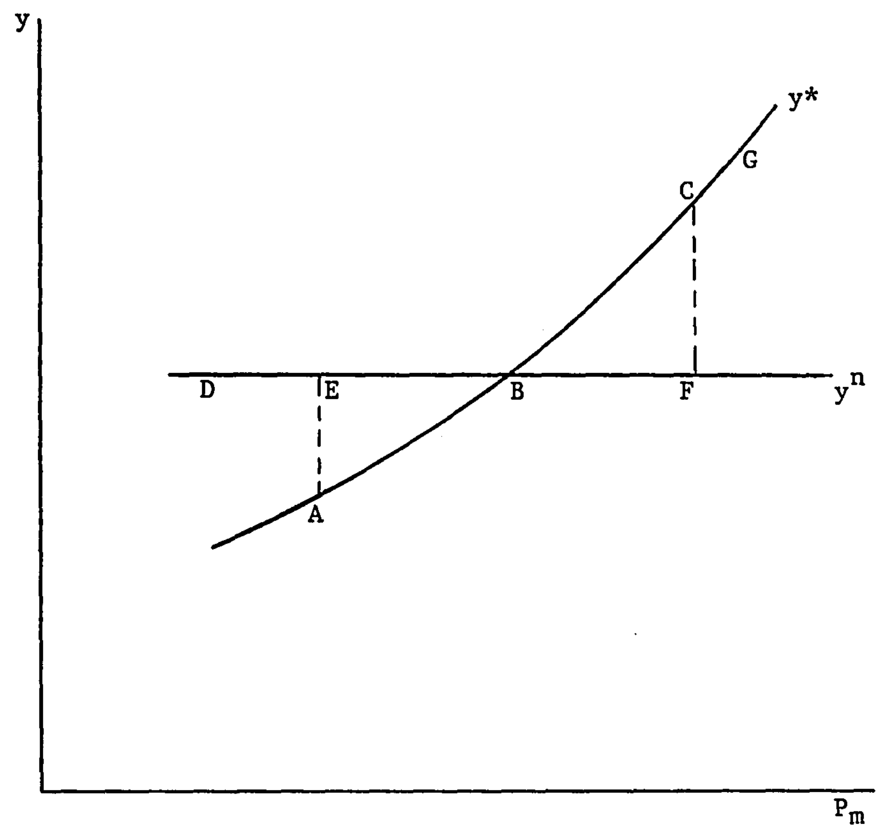


Figure 3.3. Composite output supply curve of the firm

(3.23) $\partial y^*/\partial SET\Big|_{\pi^*>\pi^n} = f_K(\cdot)\cdot\partial K^*/\partial SET + f_L(\cdot)\cdot\partial L^*/\partial SET$

$$= r\cdot[f_K(\cdot)\cdot f_{KL}(\cdot) + f_L(\cdot)\cdot f_{KK}(\cdot)]/[EPP\cdot(1-SET)^2\cdot|S|].$$

Again, except in the case of equation (3.21), refutable implications do not follow from these comparative statics. In general, the effect of a change in the set-aside requirement on total production and non-land input use is ambiguous. This is similar to the result obtained when the price of an input is changed (Silberberg 1978). Because the parameter SET does not explicitly enter the equation (3.7), a change in set-aside parameter has no effect on the non-participant producer so long as the producer continues to remain a non-participant. Of course, a change in SET might very well effect the participation decision itself.

Result 3:

> An decrease (increase) in set-aside rate will make participation more profitable and hence will not decrease (increase) the number of firms participating in the commodity program.

Proof:

$\partial Z/\partial SET = (\partial\pi^* - \partial\pi^n)/\partial SET = \partial\pi^*/\partial SET - \partial\pi^n/\partial SET = -L^*(\cdot)r/(1-SET)^2 < 0$ QED.

As in the case of support price, effects on the level of output when the shock in the SET causes the producer to switch the program decision, are indeterminate.

Paid-diversion program

Now the model is modified to include a paid-diversion program. The paid-diversion program in the U. S. has changed over the time and varied across the crops. Typically, under the paid-diversion program, government rents crop land from the willing producer for a specified rent. This land is then left idled. See USDA (1984) for details of paid-diversion program in the U.S. and how it evolved over time. Consider a stylized paid-diversion program which stipulates a paid-diversion payment rate (D) in \$/acre of idled land[6], and an idle acre requirement, DIV. Like set-aside programs, paid-diversion program is voluntary; the decision to participate in the paid-diversion program is left to the individual producer. The participating producer has to idle 100•DIV percent of the eligible crop acreage (the base acreage) to remain in compliance with the program requirements. That is, for each acre planted, the producer must control 1/(1-DIV) acres of land. In return for this, the participating producer gets paid $D per acre idled.

Although to remain eligible for paid-diversion payments, the producer must also participate in the set-aside program, examining the paid-diversion program in isolation would bring out the required results. Also, in the past, there were periods when only a paid-diversion program was in effect further indicating the necessity of examining the paid-diversion program in isolation. Expected profit for a participant is:

$$(3.24)\quad \pi = EFP \cdot f(L, K) - r\,L\,/(1-DIV) - w\,K + L \cdot D \cdot DIV/(1-DIV)$$

$$= \pi = EFP \cdot f(L, K) - r\,L\,\eta - w\,K$$

where,

$\eta = [1/(1-DIV) - (D/r) \cdot DIV/(1-DIV)]$,

DIV = fraction of base acres to be idled (idle acres requirement),

D = paid-diversion payment rate, $/acre of idled land,

and other variables are as defined above. Unlike in set-aside program, both participants and non-participants receive the same market price for the output. Note that the objective for the non-participant is nested in equation (3.24). In fact, when equation (3.24) is evaluated at DIV = D = 0, then $\eta = 1$ and profits for the non-participants $EFP \cdot f(L, K) - r\,L - w\,K$, are obtained. Clearly, if DIV and D are set by the policy maker such that $\eta > 1$ then the paid diversion program is not profitable for the producer. If $\eta > 1$, the effective rental value of land for the participant is $r \cdot \eta > r$ and hence paid-diversion program is not profitable. Thus, a condition for the producer to participate in paid-diversion program is:

(3.25) $\eta = [1/(1-DIV) - (D/r)\cdot DIV/(1-DIV)] < 1.$

Multiplying both sides by $r\cdot(1-DIV)$ and by rearranging inequality (3.25) can be rewritten:

$$r - (D)\cdot DIV < r\cdot(1-DIV)$$

which, after collecting terms can be further simplified to:

$$- (D)\cdot DIV < - r\cdot DIV,$$

or simply:

(3.26) $D > r.$

Equation (3.26) indicates that a paid-diversion program as specified, is profitable to the producer if diversion payments per acre are higher than the rental price of the land[7]. Note that, in recent Farm bills paid-diversion programs are a part of a package which requires that producers enroll in the set-aside program to be eligible for the paid-diversion program.

Multiproduct Firm

Results are now extended to multiproduct firms. Consider a technology of m outputs ($y_1, ..., y_m$) and n inputs ($x_1, ..., x_n$). Sakai (1974) has examined the behavior of a firm with such a technology. Sakai has shown that for a such multioutput multiinput firm, own price elasticities for outputs (inputs) are positive (negative), i.e., output supply curves are positively sloped and input demand curves are negatively sloped. Sakai has further shown that, in general, cross price effects are ambiguous. See Sakai (1974), and Henderson and Quandt (1980, pages 98-101) for details.

Consider a voluntary commodity program for g of the m outputs. Similar to the single product case, the set of program parameters is given by (P_{mi}, SET_i; i = 1, ..., g).

Further, assume that there are no cross compliance restrictions[8]. Thus, in this stylized model, voluntary commodity programs exist for g outputs and producer has to decide for which of these crops it is beneficial to participate in the program. This involves solving gC0+gC1+gC2+ ...+gCg-1+gCg expected profit maximization problems, where gCr = g!/[r!•(g-r)!]. For example, if commodity programs exist for two crops (g = 2) - say, rice and cotton - then the producer has the option of participating in the programs of both rice and cotton, only rice, only cotton, or none at all; the producer chooses the option where expected profits are the highest. For expository purpose, the producers decision problems under non-participation and participation in all crops is examined here.

Non-participant

The objective function for a firm that does not participant in the government program for any crop is:

(3.27) $\text{Max } E(\pi) = \sum_{i=1}^{m} ENP_i \cdot y_i - \sum_{j=1}^{n} r_j \cdot (\sum_{i=1}^{m} x_{ji}) + \lambda f(y_1, ..., y_m, x_{11}, ..., x_{nn})$

where,

$E(\pi)$ is the expected profits of the firm,

y_i is the amount of ith output produced,

x_{ji} is the amount of jth input used for the production of ith good,

ENP_i is the expected farm price of ith output,

r_j is the price of jth input,

$f(\cdot)$ is a twice differentiable implicit production function, and

λ is the Lagrange multiplier.

The choice variables in (3.27) are y_i and x_{ji}. First order necessary for (3.27) are given by:

(3.28a) $ENP_i + \lambda \cdot \partial f(\cdot)/\partial y_i = 0, \quad i = 1, ..., m,$

(3.28b) $r_j + \lambda \cdot \partial f(\cdot)/\partial x_{ji} = 0, \quad j = 1, ..., n; i = 1, ..., m,$ and

(3.28c) $f(y_1, ..., y_m, x_{11}, x_{12}, ..., x_{nn}) = 0.$

Participant

The objective function under simultaneous participation in commodity programs of all crops is:

$$(3.29)\quad \text{Max } E(\pi) = \sum_{i=1}^{g} EPP_i \cdot y_i + \sum_{i=g+1}^{m} ENP_i \cdot y_i - \sum_{j=2}^{n} r_j \cdot (\sum_{i=1}^{m} x_{ji})$$

$$- r_1 \cdot (\sum_{i=1}^{m} x_{1i}/(1-SET_i)) + \lambda f(y_1, ..., y_m, x_{11}, ..., x_{nn})$$

where,

SET_i is the set-aside requirement for ith crop, and

EPP_i is the expected price of ith product to the participant.

Other variables are as defined earlier. Note that x_1 is the land input. As in the single product case, $r_1/(1-SET_i)$ can be interpreted as the effective price of land used for ith crop. Thus, for ith good, a participating producer has an higher expected output price ($EPP_i > ENP_i$) and a higher land input price ($r_1/(1-SET_i) > r_1$). The first order necessary and second order sufficient conditions for (3.29) are:

(3.30a) $EPP_i + \lambda \cdot \partial f(\cdot)/\partial y_i = 0, \quad i = 1, ..., g,$

(3.30b) $ENP_i + \lambda \cdot \partial f(\cdot)/\partial y_i = 0, \quad i = g+1, ..., m,$

(3.30c) $r_1/(1-SET_i) + \lambda \cdot \partial f(\cdot)/\partial x_{1i} = 0, \quad i = 1, ..., m,$

(3.30d) $r_j + \lambda \cdot \partial f(\cdot)/\partial x_{ji} = 0, \quad j = 2, ..., n; \ i = 1, ..., m,$ and

(3.30e) $f(y_1, ..., y_m, x_{11}, x_{12}, ..., x_{nn}) = 0.$

Participation in all commodities is preferred to complete non-participation if expected profits from (3.29) are higher that those in (3.27). Equation (3.29) depicts the case when participation in all commodities is desired (Note that only g crops have the program.). It is, of course, possible that participation in a few of the g crops is desired; in this case equation (3.29) should be modified accordingly. In general, the producer solves gC0+gC1+gC2+ ...+gCg-1+gCg expected profit maximization scenarios (Equations

(3.27) and (3.29) represent two such scenarios.) and chooses the one where the expected profits are maximum. Using arguments similar to the single product firm, it can be shown that an increase (decrease) in the target price (set-aside requirement) of ith crop will make participation in the commodity program more profitable and hence will not decrease the number of participants in the ith crop's program. At this level of generality, cross commodity effects can not be quantified. In general, results obtained under these general conditions are indeterminate.

Summary

In this chapter a brief review of key policy instruments for U.S. commodity programs is provided. A theoretical model directly incorporating policy instruments in crop producer decision process is developed. The theoretical model indicated that, among other things, an increase (decrease) in target price (set-aside requirement) will increase the number of program participants. The preceding exposition indicated that in general, it is impossible to determine all the effects of small changes in program parameters on crop output and input use without incorporating a number of specialized assumptions. This shows that even though some insights into the implications of a commodity program can be obtained from the stylized model, it is necessary to obtain empirical information to verify these results.

In conclusion, two points are worth noting here. First it should be noted that the analysis carried so far is for an individual producer. Market level analysis can be achieved by utilizing aggregations over individual expected profit functions, output supply functions, and input demand functions. However, as firm level analysis suggested, this market level generalization would not have much to offer. Second, the decision to participate in commodity programs clearly depends on the expected price distribution and as rational expectations hypothesis suggests, this expected price distribution in turn depends upon what is anticipated on the general market participation level or the output level. Choi and Johnson (1987) examined the participation decision under rational expectations hypothesis. Rational expectations hypothesis is not used in the analysis, because this would introduce difficulties in the ensuing elaborate empirical model.

End Notes

1. The Food Security Act of 1985 provides for marketing loans. Marketing loans allow producers to repay nonrecourse price support loans at less than the announced loan rates. See Glaser (1986), and Hanthorn and Glauber (1987) for details.

2. The base acreage LB is determined for each producer on the basis of his historical plantings. Due to set-aside restriction, a participating producer faces the inequality constrain $L \leq (1\text{-SET}) \cdot LB$. This inequality constraint is not explicitly used in the present stylized model for expositional convenience and the program parameter LB does not appear in the stylized model. However, in the empirical work that follows LB enters exogenously in the model.

3. Commodity programs typically contain two "support" prices, the loan rate and target price. Since target prices are always higher than loan rates, the target price might be considered as the price floor for program participants. Target price, if it exists, corresponds to P_m in the model. The model does not explicitly distinguish loan rates and target prices, a drawback.

4. However, if the production function is homogeneous in inputs then the expansion paths are linear. In this case the factor ratio K/L is independent of the level of output. Hence we get $K^*/L^* > K^n/L^n$ (Choi and Johnson, 1987).

5. This can be easily proved for the present case using the expression, $(\partial y^*/\partial EPP) = f_K(\cdot) \cdot \partial K^*/\partial EPP + f_L(\cdot) \cdot \partial L^*/\partial EPP$ and equation (3.18).

6. In recent years, paid-diversion payment is specified in the program in $/unit of the output (For example 1.75 $/bushel of corn in the year 1988). This payment rate is multiplied by a specified program yield to obtain payment per an acre of idled land.

7. If D is sufficiently larger than r, then it is possible for η to be negative and there will be no finite maximum for the problem in (3.24). Hence, for a finite solution to (3.24) we must also assume that $\eta > 0$ which implies $D < r/DIV$. This condition is assured in reality where supply of land is extremely inelastic. Also, producers face an additional constraint requiring that acres planted should not exceed the program specified base acres.

8. Cross compliance requirements place restrictions on acres planted by participating multicrop producer. See Cochrane and Ryan (1976) and Glaser (1986) for historical details on cross compliance restrictions.

CHAPTER IV. ISSUES IN EMPIRICAL IMPLEMENTATION

This chapter shows how the theoretical model developed in Chapter III can be integrated with supply module discussed in Chapter II for empirical implementation. A number of special structural assumptions are required for application of the model. These and other issues for empirical implementation of policy and other variables are discussed in this chapter.

In the present study, crop supply module comprises of thirteen outputs (crops) four variable inputs and one fixed input. The 13 crops are: wheat, rice, corn, other coarse grains, soybeans, hay, cotton, peanuts, flaxseed and sunflower, sugar cane and sugar beet, tobacco, vegetables, fruits and nuts. These represent over 95 percent of U.S. agriculture in terms of acres planted and value of production. This 13 crop list for the U.S., will represent the most dis-aggregated estimation of crop supply response analysis. The four variable inputs are land, fertilizer, operating capital, and labor. Value of durable farm machinery is the fixed input.

Following the discussion in Chapter II, a normalized quadratic restricted profit function is used. It is restricted because there is a fixed input. Wage rate of labor is used as the numeraire price. Thirteen output supply and four input demand equations are derived from the normalized quadratic profit function. Of these, the input demand equation for the numeraire good, labor, is non-linear. The other sixteen equations are linear. Policy variables are incorporated into all equations directly in a structural way.

Policy Implementation

The commodity program provisions in the U.S. have included a number of complex features and provisions. Moreover, these provisions have changed considerably over the sample period. To make the present study manageable, a overall general structure is developed to reflect these changing characteristics of program provisions. The following treatment for program variables is one such stylized representation.

Though the commodity programs have been continuously evolving over the sample period, three basic features have remained fairly constant for the food and feed grain programs. These include commodity loan activities of the CCC, price support or deficiency payments with set-aside requirements, and paid diversion programs. The program parameters incorporated in the present study include these three basic features.

Of the 13 crops in the present study, for 5 crops (hay, flaxseed and sunflower, sugarcane and sugarbeet, vegetables and fruits and nuts) no policy variables were explicitly incorporated. These crops do not have direct domestic price support policies (see Table 1.1). Import quotas for sugar are significant, but modeling import quotas is beyond the scope of the present study. For the remaining 8 crops in the model (wheat, rice, corn, other coarse grains, soybeans, cotton, peanuts, and tobacco) policy parameters are explicitly introduced for the estimated output supply and input demand equations. Also, for soybeans and peanuts only loan rates exist. Hence, for these two crops only loan rates are modeled. All the producers of soybeans and peanuts are treated as program participants. The government program for tobacco specifies a target price but is not voluntary. Target price for tobacco are also incorporated in the estimated output supply and input demand equations. Policies for wheat, rice, corn, other coarse grains, and cotton were modeled in the most detail. Programs for these five crops involve a decision by the producers whether or not to participate.

Target prices and loan rates

The exposition in Chapter III demonstrated that target prices and loan rates effectively truncate the distribution of expected prices for the producers who participate in commodity programs. For these program participants, target prices and loan rates alter the expected prices. Specifically, the expected price is higher with support prices. To the producers who continue to remain non-participants in commodity programs, target prices have no effect on the expected prices[1]. This has two implications. First, the target prices and loan rates enter the output supply response functions via the expected prices; higher the target price higher the expected price. Second, we have two distinct expected prices, one for participants and one for non-participants. However, data are available only at the aggregate level; data on production and input use are not available for program participants and non-participants separately. Hence, only one supply response function aggregated for all producers - both participants and non-participants - can be estimated. This necessitates aggregation of the expected prices of participants and non-participants. Hence, a method had to be devised to aggregate the expected price of participants and non-participants.

One obvious choice for aggregating prices is to weigh the expected prices by participation rates. This intuitively appealing method was used. More specifically, aggregate expected price for i^{th} crop is derived as:

(4.1) $EP_i = PAR_i \cdot EPP_i + (1 - PAR_i) \cdot ENP_i$,

where,

EP_i = aggregate, expected price for i^{th} crop,

PAR_i = program participation rate,

EPP_i = expected price for program participants, and

ENP_i = expected price for non-participants.

Given participation rate (defined in detail later), EP_i in (4.1) is a linear aggregator of EPP_i and ENP_i. However, participation rate itself is endogenous and a function of prices. Thus, the aggregate measure of price, EP_i, in equation (4.1) represents nonlinear aggregation of individual firm's prices. This non-linear aggregation of firm specific prices imposes certain restrictions on the functional forms of aggregate market-level profit function (see Table 2.1). To maintain theoretical consistency, these aggregation restrictions are maintained in the specification of market-level profit function.

Simple adaptive expectations are used to derive the expected prices. Specifically, expected price for non-program participants is defined as the market price, lagged one period. Using more sophisticated approaches such as rational expectations (Muth, 1961; Goodwin and Sheffrin, 1982) would substantially complicate the present model. To keep the study manageable, simple adaptive expectations are used instead. Expected price for program participants is defined as the maximum of current target price, loan rate, and lagged market price.

The treatment given in equation (4.1) is relevant only for wheat, rice, corn, other coarse grains, and cotton for which the program participation rate in endogenized. For soybean and peanuts expected price simply equals maximum of current loan rate and market price lagged one period. For tobacco, the aggregate expected price equals the maximum of the current target price and market price lagged one price. For the remaining 5 crops (hay, flaxseed and sunflower, sugarcane and sugarbeet, vegetables and fruits and nuts) aggregate expected price was set equal to market price, lagged one period.

Set-aside requirements

As explained in Chapter III, set-aside requirements increase the "effective" rental price of land input to program participants. Thus, to be consistent with the theoretical model in Chapter III, set-aside requirements should enter the empirical model through the rental price of land. However, set-aside requirements are crop specific and depending on the commodity program provisions, differ from crop to crop. Hence, the set-aside requirements affect rental price of land in a crop specific manner. The implication is that effective rental price of land depends on where the land input is being used. The higher the set-aside requirements for i^{th} crop (relative to j^{th} crop) the higher is the rental price of land planted to i^{th} crop.

Following the treatment in Chapter III, rental price of land for crop i for a program participant is defined as $RENT/(1-SET_i)$, where RENT is the rental price of land and SET_i is the set-aside requirements. For a non-participant the rental value of land remains to be RENT. Similar to crop output price, rental price of land had to be aggregated over participants and non participants. As before, participation rate is used as the weight.

The aggregate rental price of land used for i^{th} crop is given by:

(4.2) $ARENT_i = PAR_i \cdot RENT/(1-SET_i) + (1-PAR_i) \cdot RENT$

where,

$ARENT_i$ = aggregate effective rental price of land for ith crop, \$/acre,

RENT = rental price of land, \$/acre,

$PART_i$ = participation rate in i^{th} crops' commodity program, and

SET_i = set-aside requirements for i^{th} crop.

Like the output price, the specification of "effective" rental value of land input in equation (4.2) is relevant only for wheat, rice, corn, other coarse grains and cotton. For the remaining 8 crops in the model, there is no acreage reduction program. Hence the rental price of land for these 8 crops simply equal to RENT.

Diversion payments

The essential feature of the paid-diversion instrument is that government effectively rents a certain percent of land at an announced price from willing producers. This "diverted" land is left idle. Though paid-diversion programs have changed considerably over the sample period this feature remained the same. In the present study, paid-diversion programs are incorporated in the product supply equations for wheat, corn and other coarse grains.

A similar program was legislated in the 1981 Farm Bill for rice. However lack of observations prevented incorporating the paid-diversion program in the supply equations for rice. The paid-diversion program for cotton has changed over the sample period, making it difficult to model in a stylized fashion. For this reason, a paid-diversion program for cotton is not specified in the output supply equations.

The discussion in Chapter III indicated that a paid-diversion program has two distinct effects on the production. First, a paid-diversion program has no effect on the non-participant producer's production as long as the producer continues to remain a non-participant[1]. Second, the program has a direct effect, though not unambiguous in direction, on the production of the participant.

Of course, the paid-diversion program will have a definite influence on the participation decision itself. This implies that at aggregate level, effect of paid-diversion program is best represented by weighing with the participation rate. Accordingly, paid-diversion program in the supply equations of wheat, corn and other coarse grains is represented by a multiplicative variable. This variable is obtained by taking the multiplicative product of participation rate, paid-diversion payment rate (PDP), and paid-diversion idle acres requirement (DIV)[2].

Program participation

One of the keys to analyzing effects of commodity policies is the identification of the proportion of producers participating in the programs. The conceptual foundations of the supply response model developed in Chapter III indicated that the group supply functions could be determined by aggregating over all participants and non-participants. This would require data on the number of producers eligible for government programs who participate and the number of producers eligible that do not participate. Unfortunately, these data are not generally available. However, there are data available on the number of acres under participating farms. Although there is not a one-to-one correspondence between the number of acres and number of producers, it was felt that these data represented a reasonable proxy. Accordingly, participation rate for a crop was defined as the percent of base acres (eligible acres) brought under the control of program provisions.

Participation rate is an important indicator of the effectiveness or popularity of a commodity program. Structural aggregate supply response analysis must reflect changes in program participation. Reduced form representations of policies fail to recognize the changes in participation rate explicitly. Thus, the policy results from such reduced form studies are difficult to apply in circumstances other than those that existed in the sample. Unlike previous supply response studies (e.g., Shumway and Alexander 1988, and Ball 1988), participation rates are endogenized in this study.

The conceptual model set up in Chapter III indicated that participation rate in the commodity program for i^{th} crop depends on:

(4.3) $$PAR_i = f(\Pi^{*i} - \Pi^{ni}),$$

where,

PAR_i = participation rate (proportion of base acres under program),

Π^{*i} = profits for program participant,

Π^{ni} = profits for non-program participant, and

$\partial f(\cdot)/\partial(\Pi^{*i} - \Pi^{ni}) \geq 0$.

Unfortunately, however, a direct empirical implementation of (4.3) is not possible because data are not available for Π^{*i} and Π^{ni}. However, the analysis in Chapter III, showed that among other variables target prices and set-aside requirements explain the difference between Π^{*i} and Π^{ni}. Specifically, the comparative statics analysis in Chapter III indicated that $\partial(\Pi^{*i} - \Pi^{ni})/\partial TP_i \geq 0$, $\partial(\Pi^{*i} - \Pi^{ni})/\partial SET_i \leq 0$, and $\partial(\Pi^{*i} - \Pi^{ni})/\partial PDP_i \geq 0$, where TP_i is the target price of i^{th} crop, SET_i is the set-aside requirement for i^{th} crop, and PDP^i is the deficiency payment per unit of i^{th} crop.

These comparative statics results are used in specifying an empirical version of equation (4.3). Additionally, selected restrictions are placed on the functional form so that participation rate is bound between 0 and 1. These restrictions are warranted because the dependent variable, PAR_i, itself is bound between 0 and 1 by definition. The exact functional form for participation rate is:

(4.4) $PAR_i = 1\text{-}\exp[-\{a_{i1} \cdot (TP_{ti}/FP_{it-1}) \cdot (1\text{-}SET_i\text{-}DIV_i) + a_{i2} \cdot (PDP_i/FP_{it-1}) \cdot DIV_i\}]$,

where,

TP_i = target price for i^{th} crop,

FP_{it-1} = farm price of ith crop, lagged one period,

a_{i1} and a_{i2} are parameters to be estimated and other variables are as defined earlier. Variables without a time subscript refer to current period. A prior, we expect a_{i1} and a_{i2} to be positive.

The functional form of equation (4.4) has several desirable properties. First, the functional form ensures that for $TP_t \geq 0$, $PDP_{it} \geq 0$, $FP_{t-1} \geq 0$, $0 \leq SET_i \leq 1$, and $0 \leq DIV_i \leq 1$ predicted values for PAR_i are bound between 0 and 1. The simple linear functional form used by previous studies (Skold and Westhoff, 1988) does not satisfy this restriction. Other desirable properties of the specification in (4.4) become evident by observing its first and second derivatives,

(4.5a) $\partial PAR_i/\partial TP_i = (1 - PAR_i) \cdot (a_{i1}/FP_{it-1})(1 - SET_i - DIV_i) \geq 0$,

(4.5b) $\partial PAR_i/\partial PDP_i = (1 - PAR_i) \cdot (a_{i2}/FP_{it-1}) \cdot DIV_i \geq 0$,

(4.5c) $\partial PAR_i/\partial SET_i = (PAR_i - 1) \cdot a_{i1} \cdot (TP_i/FP_{it-1}) \leq 0$, (4.5d) $\partial PAR_i/\partial DIV_i = (1 - PAR_i)\cdot\{-a_{i1}(TP_i/FP_{it-1}) + a_{i2}(PDP_i/FP_{it-1})\}$,

and

(4.6a) $\partial^2 PAR_i/\partial TP_i^2 = -(\partial PAR_i/\partial TP_i)\cdot(a_{i1}/FP_{it-1})(1 - SET_i - DIV_i) \leq 0$,

(4.6b) $\partial^2 PAR_i/\partial PDP_i^2 = -(\partial PAR_i/\partial PDP_i)\cdot(a_{i2}/FP_{it-1})\cdot DIV_i \leq 0$,

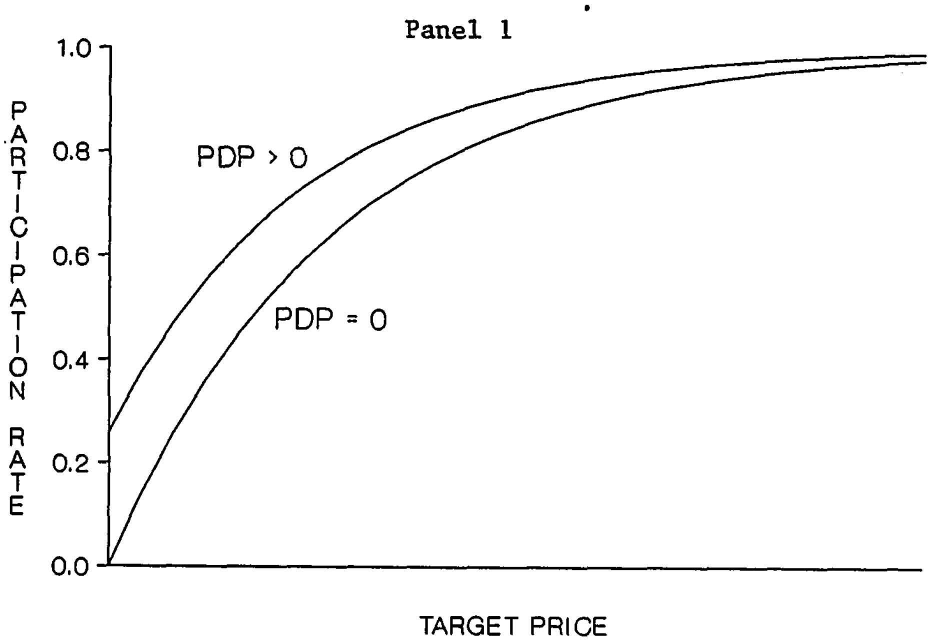
(4.6c) $\partial^2 PAR_i/\partial SET_i^2 = -(\partial PAR_i/\partial SET_i)\cdot a_{i1}\cdot(TP_{ti}/FP_{it-1}) \geq 0$, and

(4.6d) $\partial^2 PAR_i/\partial DIV_i^2 = (\partial PAR_i/\partial DIV_i)\cdot\{a_{i2}(TP_i/FP_{it-1})\cdot DIV_i - (a_{i1}(PDP_i/FP_{it-1})\}$.

Equations (4.5) and (4.6) indicate that the participation rate approaches 1 as target price (TP_i) or paid-diversion payment rate (PDP_i) approach infinity. Thus, for a sufficiently large target price or paid-diversion payment rate, policy maker can assure that all producers participate in the commodity programs. These properties of the participation rate equation are illustrated in panel 1 and panel 2 of Figure 4.1. As shown in the Figure 4.1, when target price and paid-diversion payment rate are zero, then there is no participation in the program ($PAR_i = 0$).

The first derivative of equation (4.4) with respect to set-aside requirement is given in equation (4.5c) which indicates that participation rate is inversely related to set-aside requirement rate. Evaluating equation (4.4) at $SET_i = 1$ (which of course implies $DIV_i = 0$) gives a participation rate of 0 as desired.

While $\partial PAR_i/\partial SET_i$ is clearly non-positive, the sign of $\partial PAR_i/\partial DIV_i$ in equation (4.5d) can not be ascertained with out the knowledge of parameters a_{i1} and a_{i2}, and the level of policy parameters TP_i, and PDP_i in relation to the market price (FP_i). This is because an increase in DIV_i has two effects, acting in opposite directions. Since an increase in DIV_i reduces acres available for planting there is a potential loss of gross revenue leading to a negative effect on the participation rate. On the other hand, an increase in DIV_i makes the program more attractive; leading to a positive effect on the program participation. The overall net effect of a change in DIV_i on program



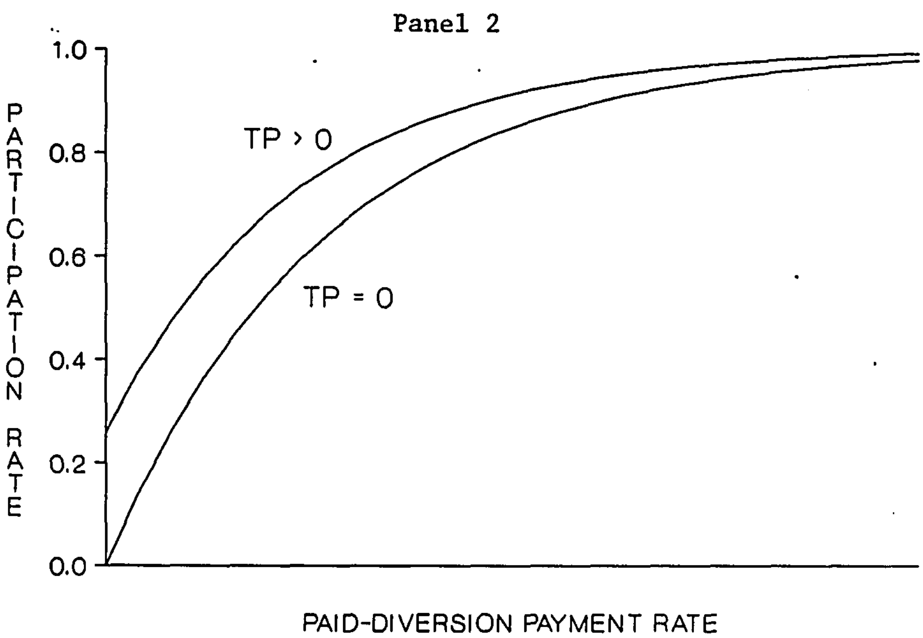


Figure 4.1. **Response of program participation rate to target price and paid-diversion payment rate**

participation rate can not be obtained without knowing the values of parameters a_{i1} and a_{i2}. Empirical estimation of equation (4.4) will reveal these coefficients.

Program participation rate equations are estimated for wheat, rice, corn, other coarse grains, and cotton. For other crops in the study, similar programs do not exist and hence program participation equations are not necessary. Note that the treatment of policy variables and their incorporation in empirical model follows closely the theoretical specification in Chapter III. This structural representation, as opposed to reduced form representation, will enrich the policy analyzing capability of the estimated crop module.

Fixed Variables and Technology

Value of durable farm machinery is treated as a fixed variable. As indicated in Chapter II, exact linear aggregation of the fixed input across the firms imposes restrictions on the functional form of the profit function. Specifically, it requires that profit function be affine in the fixed input - value of durable farm equipment (see Table 2.1). This condition is maintained in the specification and the estimation of the supply module[3].

Various technological advancements like hybrid seed development, better crop protection measures, improved soil tillage practices etc., have enhanced crop yields over the sample period. To capture the effects of such technical progress on crop yields and input productivity, a time variable is included in the model. This time variable is used in the thirteen crop supply and four input demand equations.

Other fixed variables in the model include four dummy variables. These dummy variables are used in the output supply equations for corn, peanuts and flaxseed and sunflower. Extremely bad weather coupled with an aggressive payment-in-kind (PIK) program resulted in a dramatically lower corn production in year 1983[4]. To capture these effects, a dummy variable for year 1983 was used in the corn supply equation.

Similarly, to capture the effects of a bad weather year, a dummy variable for year 1980 was used in the product supply equation of peanuts[5]. Flaxseed and sunflower production were the most erratic. Two dummy variables, one for year 1979 and for years later to 1977 were used in the production equation of flaxseed and sunflower.

Comparative Statics[6]

Before proceeding to estimation it will be worthwhile to ascertain how the market level empirical specification of the policy in the supply module behaves. This can be evaluated by examining the comparative statics of the empirical model. The relevant equations for the program crops (wheat, rice, corn, other coarse grains, and cotton) are:

(4.7a) $Y_i = a_i + \sum_{j=1}^{q-1} b_{ij}\, EP_j + \sum_{k=1}^{K} f_{ij} Z_k,$

(4.7b) $EP_i = PAR_i \cdot EPP_i + (1 - PAR_i) \cdot ENP_i,$

(4.7c) $EPP_i = \max(TP_i, FFP_{t-1}),$

(4.7d) $ENP_i = FP_{t-1},$

(4.7f) $EP_{14} = ARENT_i = PAR_i \cdot RENT/(1-SET_i) + (1-PAR_i) \cdot RENT$, and

(4.7e) $PAR_i = 1-\exp[-\{a_{i1} \cdot (TP_{ti}/FP_{it-1}) \cdot (1-SET_i-DIV_i) + a_{i2} \cdot (PDP_i/FP_{it-1}) \cdot DIV_i\}].$

Equations (4.7b) through (4.7f) are definitional equations and have no parameters to be estimated. Note that while equations (4.7a) and (4.7f) are estimated for the program crops, only (4.7a) is estimated for the remaining 8 crops (soybeans, hay, peanuts, flaxseed and sunflower, sugarcane and sugarbeet, tobacco, vegetables, and fruits and nuts). Also, for these 8 crops equations (4.7b) through (4.7f) are not appropriate and are replaced by:

(4.8a) $EP_i = FP_{t-1}$, and

(4.8b) $EP_{14} = RENT.$

The comparative statics analysis for the non-program crops is straight forward and hence is not presented. The comparative statics analysis is carried out here only for the program crops whose equations are given by (4.7).

Changes in target prices

To analyze the effects of a change in target price of ith crop on the production differentiate (4.7a) with respect to TP_i;

(4.9) $\partial Y_i/\partial TP_i = b_{ii}\ (\partial EP_i/\partial TP_i) + b_{i14}\ (\partial ARENT_i/\partial TP_i)$.

By the convexity of the profit function, $b_{ii} \geq 0$ implying a positively sloped supply function. For a normal technology (Sakai, 1974), we expect $b_{i14} \leq 0$, a priori. The first term on the right hand side of equation (4.9) is positive. To show this, using equations (4.7b) and (4.7c), the first term in equation (4.9) can be rewritten as:

$$\partial EP_i/\partial TP_i = (EPP_i - ENP_i)\cdot(\partial PAR_i/\partial TP_i) + PAR_i\cdot(\partial EPP_i/\partial TP_i).$$

From equations (4.7c) and (4.7d), $(EPP_i - ENP_i) \geq 0$; that is, expected price for program participant is not less than that for the non-participant. Second, from equation (4.5a), $(\partial PAR_i/\partial TP_i) \geq 0$; that is, participation rate increases as target price increases. Finally, from equation (4.7c) we obtain $(\partial EPP_i/\partial TP_i) \geq 0$. Thus, the first term on the right hand side of equation (4.9) is non-negative; $b_{ii}\cdot(\partial EP_i/\partial TP_i) \geq 0$. This positive effect signifies an expansion effect of the target price; higher the target price higher the production.

The second term on the right hand side of equation (4.9), $b_{i14}\cdot(\partial ARENT_i/\partial TP_i)$ is non-positive. This can be shown by differentiating the right hand side of equation (4.7f) with respect to TP_i;

$$(\partial ARENT_i/\partial TP_i) = RENT\cdot[SET_i/(1-SET_i)]\cdot(\partial PAR_i/\partial TP_i).$$

But, since set-aside requirements (SET_i) are always between 0 and 1, and $(\partial PAR_i/\partial TP_i) \geq 0$ (from equation 4.5a), we obtain $(\partial ARENT_i/\partial TP_i) \geq 0$. Thus, the second term on the right hand side of (4.9) is negative, as claimed. This negative effect of an increase in target price on production is due to an increase in the participation rate and the associated loss in acres due to set-aside requirements. Thus, equation (4.9) indicates that an increase in target price would have two distinct effects on production acting in opposite directions. The effect on producers who are already program participants is positive. In fact, when (4.9) is evaluated at $PAR_i = 1$, we unambiguously obtain $\partial Y_i/\partial TP_i \geq 0$.

Changes in set-aside requirements

To investigate, the effects of a change in set-aside requirements on the production, differentiate equation (4.7a) with respect to SET_i:

(4.10) $\partial Y_i/\partial SET_i = b_{ii}\ (\partial EP_i/\partial SET_i) + b_{i14}\ (\partial ARENT_i/\partial SET_i)$.

The first term on the right hand side of (4.9) is non-positive, because from equation (4.7b) we get,

$$(\partial EP_i/\partial SET_i) = (EPP_i - ENP_i)\cdot(\partial PAR_i/\partial SET_i).$$

From equation (4.5c), we know $(\partial PAR_i/\partial SET_i) \leq 0$. Thus, the first term on the RHS of equation (4.10) is non-positive. The sign of second term on the RHS of equation (4.10) is positive because from equation (4.7f) we get:

$$(\partial ARENT_i/\partial SET_i) = [RENT_i\cdot SET_i/(1-SET_i)]\cdot(\partial PAR_i/\partial SET_i) - PAR_i\cdot RENT_i/(1-SET_i)^2,$$

which is clearly negative. However when multiplied by b_{i14}, the second term on the RHS of (4.10) becomes positive thus making the whole expression in (4.10) in determinate in sign. As in the case of target price, a change in set-aside requirement has two distinct and opposite effects on the total production.

The comparative static results from the empirical model are consistent with the results obtained from the theoretical model set up Chapter III. To obtain, tangible unambiguous results it is necessary to estimate the parameters of the model.

Concluding Remarks

This chapter has focussed on the structural and technological assumptions necessary to empirically implement the theoretical model developed in Chapter III. An important feature of the model includes aggregate output supply and input demand equations which are consistent with expected profit maximization by individual agents. Thirteen output supply and four input demand equations are derived from an aggregate normalized profit function. Policy variables (target prices, loan rates, set-aside requirements, paid-diversion payment rates, and paid-diversion requirements) are explicitly introduced in these output supply and input demand equations in a structural framework. Additionally, program participation rate equations that interact with output supply and input demand equations are outlined for estimation. These participation rate equations reflect the voluntary nature of the commodity programs. The structural model developed here represents a significant improvement over the way policy variables are introduced in previous studies of output supply and input demand analysis.

A caveat is in order. Previous studies by Choi and Johnson (1987) and Holt (1987) have examined producer decisions in the context of voluntary commodity programs using rational expectations hypothesis (REH). This theoretically elegant REH lets the individual producer's price expectations a function of all relevant information including anticipated market output and anticipated total participation rate. Accordingly, when a policy parameter is changed, the expectations change and hence, output and input levels of a non-participant might also change. This market feedback mechanism between participation non-participation and expected price is lost in a simple adaptive expectations framework used in the present study. However, in view of the ensuing large scale estimation, REH is not used in the present study.

End Notes

1. This result is a direct consequence of lack of rational expectations hypothesis (REH). In the model, price expectations of the non-participant producer do not change when policy instruments are shocked. Hence, if the producer continues to remain a non-participant even after a change in policy parameter, then the non-participant producer's optimal output and input levels are unchanged. On the other hand, if REH is used, then price expectations of the non-participant producer change as policy parameter is varied and hence output produced also changes.

2. The paid-diversion requirement (DIV) variable used in the model differs from the actual instrument given in the program provisions. In the model, DIV is specified as exogenous. However, historically during certain year, producers had the option of choosing DIV (subject to an upper limit). The formula used to derive DIV is explained in Chapter V.

3. More specifically, coefficients (d_{kl} in equation 2.8) for the quadratic terms of fixed variables are set to zero .

4. Corn production was 4.2 billion bushels in year 1983, the lowest in the last 20 years. The average annual corn production for the previous two years was about 8.2 billion bushels.

5. In 1980, peanut production was 2.3 billion pounds compared to an average of 4 billion pounds in the previous two years.

6. To simplify the results, no paid-diversion program is assumed in the comparative static analysis, i.e., results of the comparative static analysis are implicitly evaluated at $DIV_i = 0$ or $PDP_i = 0$. The ensuing empirical model incorporates a paid-diversion program as explained.

CHAPTER V. DATA AND ESTIMATION

This chapter describes the data set used for the estimation. This documentation of the data base is followed by a description of the estimation procedures used for the empirical investigation of the supply module for the U.S. crops sector.

Data

Aggregate annual crop-year data for the U.S. were used in the estimation. The sample period extends from years 1950 to 1986. However, due to the lag structure involved in the specification of the analytical model, only 36 observations (1951-1986) are available for the estimation. Endogenous variables include the thirteen outputs (production of wheat, rice, corn, other coarse grains, soybeans, hay, cotton, peanuts, flaxseed and sunflower, sugarcane and sugarbeet, tobacco, vegetables, and fruits and nuts), four variable inputs (crop land used, quantity of fertilizer applied, quantity of operating capital used, and labor employed in crop sectors) and the commodity program participation rates for wheat, rice, corn, other coarse grains, and cotton. The exogenous variables include the prices of outputs and variables inputs, target prices, set-aside requirements, paid-diversion payment rates, and paid-diversion idled acres requirements. Table 5.1 lists the variable definitions with explanations, units and sources of data. Complete data used for estimation are given Table A.1 in the Appendix. Data for outputs and variable inputs are in terms of physical quantities rather than value.

The Tornquist approximation to Divisia index was used as necessary to aggregate price data for the output and input groups. Value shares for outputs and expenditure shares for inputs are used as weights. Aggregate quantity indices are computed by dividing aggregate values and expenditures by the aggregate price indexes. The Tornquist approximation to Divisia price index for a group of n commodities is given by (Tornquist 1936, Diewert, 1976, Trivedi, 1981):

Table 5.1. Description of variables, units, and data sources

Variable	Explanation	Units	Source
WHEPD	Wheat, production	Million bushels	AS[a]
RICPD	Rice, production	Million cwt	AS
CORPD	Corn, production	Million bushels	AS
OCGPD	Other coarse grains, production	Index	Derived
SOYPD	Soybeans, production	Million bushels	AS
HAYPD	All Hay, production	Million tons	AS
COTPD	Cotton, production	Million pounds	AS
PNTPD	Peanuts, production	Million pounds	AS
FXSPD	Flaxseed and Sunflower, production	Index	Derived
SUGPD	Sugarcane and beet, production	Index	Derived
TOBPD	Tobacco, production	Million pounds	AS
VEGPD	Vegetables, production	Million tons	AS
FUNPD	Fruits and Nuts, production	Index	Derived
LNDUS	Land use	Million acres	Derived
FERUS	Fertilizer use	Million tons	AS
OPCUS	Other operating capital	Index	Derived
LABUS	Labor use in Crop Production	Million hours	Derived
WHEFP	Wheat, farm price	$/bushel	AS
RICFP	Rice, farm price	$/cwt	AS
CORFP	Corn, farm price	$/bu	AS
OCGFP	Other coarse grains, farm price	DI (1950=1)	Derived
SOYFP	Soybeans, farm price	$/bu	AS
HAYFP	All hay, farm price	$/ton	AS
COTFP	Cotton, farm price	$/lb	AS
PNTFP	Peanuts, farm price	$/lb	AS
FXSFP	Flaxseed and sunflower, farm price	DI (1950=1)	Derived
SUGFP	Sugarcane and beet, farm price	DI (1950=1)	Derived
TOBFP	Tobacco, farm price	$/lb	AS
VEGFP	Vegetable, farm price	$/ton	AS
FUNFP	Fruits and Nuts, farm price	Index (1950=1)	AS
RENT	Land, rental value	$/acre	Derived
FERFP	Fertilizer, farm price	Index (1950=1)	AS
OPCFP	Other operating capital, price	DI (1950=1)	Derived
WAGE	Farm wage rate	$/hour	AS
VFM	Value of durable farm machinery used in the U.S. crop sector	Billion $	AS

[a]U.S. Department of Agriculture, Agricultural Statistics, various issues.

Table 5.1. (continued)

WHEEP	Wheat, aggregate expected price	$/bushel	AS
RICEP	Rice, aggregate expected price	$/cwt	AS
COREP	Corn, aggregate expected price	$/bu	AS
OCGEP	Other coarse grains, aggregate expected price	DI (1950=1)	Derived
SOYEP	Soybeans, aggregate expected price	$/bu	AS
HAYEP	All hay, aggregate expected price	$/ton	AS
COTEP	Cotton, aggregate expected price	$/lb	AS
PNTEP	Peanuts, aggregate expected price	$/lb	AS
FXSEP	Flaxseed and sunflower, aggregate expected price	DI (1950=1)	Derived
SUGEP	Sugarcane and beet, aggregate expectedprice	DI (1950-1)	Derived
TOBEP	Tobacco, aggregate expected price	$/lb	AS
VEGEP	Vegetable, aggregate expected price	$/ton	AS
FUNEP	Fruits and Nuts, aggregate expected price	Index (1950=1)	AS
WHETP	Wheat, target price	$/bu	AS
RICTP	Rice, target price	$/cwt	AS
CORTP	Corn, target price	$/bu	AS
OCGTP	Other coarse grains, target price	$/bu	Derived
COTTP	Cotton, target price	$/lb	AS
TOBTP	Tobacco, target price	$/lb	AS
WHELR	Wheat, loan rate	$/bu	AS
RICLR	Rice, loan rate	$/cwt	AS
CORLR	Corn, loan rate	$/bu	AS
OCGLR	Other coarse grains, loan rate	$/bu	Derived
SOYLR	Cotton, loan rate	$/lb	AS
PNTLR	Tobacco, loan rate	$/lb	AS
WHESET	Wheat, set-aside requirement	%	AS
RICSET	Rice, set-aside requirement	%	AS
CORSET	Corn, set-aside requirement	%	AS
OCGSET	Other c.gr., set-aside requirement	%	Derived
COTSET	Cotton, set-aside requirement	%	AS
WHEPAR	Wheat, participation rate	%	AS
RICPAR	Rice, participation rate	%	AS
CORPAR	Corn, participation rate	%	AS
OCGPAR	Other c.gr., participation rate	%	Derived
COTPAR	Cotton, participation rate	%	AS

Table 5.1. (continued)

WHEPDP	Wheat, paid-diversion payment rate	$/bu	AS
RICPDP	Rice, paid-diversion payment rate	$/cwt	AS
CORPDP	Corn, paid-diversion payment rate	$/bu	AS
OCGPDP	OCG paid-diversion payment rate	$/bu	Derived
COTPDP	Cotton, paid-diversion payment rate	$/lb	AS
WHEDIV	Wheat, diversion requirement	%	AS
RICDIV	Rice, diversion requirement	%	AS
CORDIV	Corn, diversion requirement	%	AS
OCGDIV	Other c.gr., diversion requirement	%	Derived
COTDIV	Cotton, diversion requirement	%	AS
DUM83	Dummy for year 1983	-	Derived
DUM80	Dummy for year 1980	-	Derived
DUM79	Dummy for year 1979	-	Derived
SFT77	Dummy for years after 1977	-	Derived

(5.1) $D_t = \sum_{i=1}^{n} (1/2)\{ P_{it} \cdot Q_{it}/E_t + P_{it-1} \cdot Q_{it-1}/E_{t-1}\} \cdot \log(P_{it}/P_{it-1})$, and

(5.2) $P_t = P_{t-1} \cdot \exp(D_t)$,

where,

$E_t = \sum_{i=1}^{n} P_{it} \cdot Q_{it}$,

P_{it} = Price of ith good,

Q_{it} = Production of ith good, and

P_t = Divisia price index.

The implicit quantity index, Q_t, is obtained by:

(5.3) $Q_t = E_t/P_t$.

Output and input quantities and their respective prices are scaled such that the units of gross returns (production times output price) and expenditures (input use times input price) are always millions of dollars.

Output variables

Data for the production and farm prices of wheat, rice, corn, soybeans, hay, cotton, peanuts, tobacco, and vegetables were collected from various issues of Agricultural Statistics (USDA). These data are presented in Table A.1 in the Appendix. Since data for these nine crops are readily available, aggregation of data is not necessary. The remaining four output groups (other coarse grains, flaxseed and sunflower, sugarcane and sugarbeet, and fruits and nuts), however, represent more than one crop. Hence some aggregation is necessary to arrive at the output and price measures for these four groups.

Other coarse grains (OCG) This aggregate output category comprises of barley, oats, sorghum and rye. Farm price of OCG (OCGFP) was derived using a Divisia price index as specified in equations (5.1) and (5.2). Aggregate production index for OCG (OCGPD) was obtained by using the formula in equation (5.3). The derived price and quantity indices are given Table A.1.

Sugarcane and sugarbeet (SUG) A Divisia price index was used to aggregate the farm prices of sugarcane and sugarbeet. An implicit quantity index was obtained by dividing the aggregate value of sugarcane and sugarbeet by the Divisia price index. Data on production and prices for sugarcane and sugarbeet were collected from Agricultural Statistics. The derived price and quantity indices are presented in Table A.1.

Flaxseed and sunflower (FXS) This output group comprises of flaxseed and sunflower. Divisia price index and implicit quantity index are developed by using (5.2) and (5.3). Data were collected from various issues of Agricultural Statistics.

Fruits and nuts (FUN) Using the available data on aggregate price index and cash receipts for fruits and nuts, an implicit quantity index was obtained.

Policy variables

As mentioned earlier, the commodity programs for U.S. crops have changed during the sample period. During some years there are no government programs for certain crops. Data for policy variables by crop were then collected only for those years in which a program existed for that crop.

Target prices Data on target prices for wheat, rice, corn, cotton, and tobacco were collected from various issues of Agricultural Statistics. Target prices for sorghum, barley, and oats were aggregated into a Divisia target price index for OCG. For other crops, there are no target prices. Data on target prices are presented in Table A.1. A value of zero under target price in Table A.1 indicates that there is no target price for that crop in that particular year.

Loan rates During program years, data on loan rates for wheat, rice, corn, soybeans, and peanuts were collected from various issues of Agricultural Statistics. Loan rates for sorghum, barley, oats, and rye are aggregated into a Divisia loan rate index for OCG using value shares as weights. For other crops, there are no loan rates. Data on loan rates are presented in Table A.1. As with target prices, a value of zero for loan rate in Table A.1 indicates that there is no loan rate for that crop in that particular year.

Set-aside requirements During sample years, set-aside requirements for wheat, rice, corn, other coarse grains, and cotton are derived as follows:

(5.4) $SET_i = SAC_i/(SAC_i + DAC_i + PAC_i)$ $i = 1,2,3,4,7$

where,

SET_i = set-aside requirement for i^{th} crop (fraction of base aces to be idled),

SAC_i = area idled under set-aside for i^{th} crop, million acres,

DAC_i = area idled under paid-diversion program for i^{th} crop, million acres, and

PAC_i = area planted in the program for i^{th} crop, million acres.

Program planted acres and idled acres for other coarse grains were obtained by adding the respective acres for sorghum, barley, and oats. These data were collected from ASCS fact sheets. A value of zero for SET_i in Table A.1 indicates that the program provisions for that crop in that particular year did not contain acreage reduction program (hence no set-aside requirements).

Participation Rates During sample years, program participation rate for crop z, is defined as:

(5.5) $PAR_i = (SAC_i + DAC_i + PAC_i)/BAC_i$ $i = 1,2,3,4,7$

where,

PAR_i = participation rate (fraction of base acres in compliance with the program for i^{th} crop, and

BAC_i = base area (eligible for the program) for i^{th} crop, million acres.

Other variables are as defined in (5.4). Data on base acres were obtained from ASCS fact sheets. Base aces for OCG were obtained by adding those of sorghum, barley, and oats.

Diversion payments During sample years, diversion payments per unit of output is derived by using the following formula:

(5.6) $DPA_i = DVP_i / (DAC_i \cdot PYD_i) i = 1,2,3,4,7$

where,

DPA_i = diversion payments per unit of i^{th} crop,

DVP_i = total paid-diversion payments to farmers of i^{th} crop, million \$, and

PYD_i = program yield of i^{th} crop.

Total paid-diversion payments to OCG farmers were obtained by adding the payments to sorghum, barley, and oats producers.

Variable inputs

Land Data on land use were obtained by adding the total acres planted under the thirteen crops (for sugarcane and hay acres harvested is used instead), total acres idled under commodity programs and total acres idled under the Conservation Reserve Program. Data on acres planted were collected from Agricultural Statistics. Data on acres idled were collected from ASCS fact sheets. Data on the total land use are presented in Table A.1.

Rental value of land An approach similar to user cost of capital (Branson 1979) was used to compute rental price of land. Specifically, the following formula was used to arrive at the rental price of land:

(5.7) $RENT = V \cdot (ir + tr) - g$

where

RENT = user cost or rental price of land,

V = Value of agricultural land, \$/acre,

ir = nominal interest rate,

tr = real estate tax rate, and

g = expected rate of change of RENT (expected capital gain).

Data on the value of agricultural land, interest rate and taxes were collected from various issues of Agricultural Statistics. The interest rate used was the average interest rate on new loans of federal land banks. Finally expected price changes to measure expected capital gain (g) is obtained by taking a ten year average of actual inflation rate (Moschini, 1988b).

Fertilizer The input which contributes to crop production is not fertilizer per se, but rather the actual nutrients contained in fertilizer. The primary nutrients are: nitrogen (N), available phosphoric acid (P_2O_5) and potash (K_2O). These nutrients are sold in various combinations. Mixed grade fertilizers contain more than one nutrient. To keep the model manageable, it is desirable to treat fertilizer as a single input in the production process. Data are available (in Agricultural Statistics) on the use of all fertilizers containing primary nutrients. Since different fertilizers contain different quantities of the primary nutrients, this data, as such, are not useful. Data on total fertilizer was then derived by using the formula:

(5.8) FERUS = ALLFER • (N% + P% + K%)

where,

FERUS = total primary nutrients use, in million tons,

ALLFER = quantity of all fertilizers containing primary nutrients used,

N% = Nitrogen percentage in the ALLFER,

P% = Phosphoric acid percentage in ALLFER, and

K% = Potash percentage in ALLFER.

Data on all these variables were obtained from Agricultural Statistics. The variable FERUS was employed as aggregate fertilizer input use in the estimation. Data on fertilizer price index (FERFP) was collected from Agricultural Statistics. Data on FERUS and FERFP are presented in the Table A.1.

Operating capital Operating capital comprises of expenditures on seed, lime, pesticides, petroleum products, electricity and other production expenses. The last category includes repairs and maintenance of capital items, machine hire and custom work, marketing, storage and transportation expenses, and other items reported as "miscellaneous expenses" in Economic Indicators in Farm Sector (USDA, 1986). Miscellaneous expenses consist of production fees, farm supplies, tool and shop equipment, insurance of motor vehicles, management expenses, etc. Crop sector specific data are not available on the use of (expenses of) petroleum products, electricity and other input use. However data on total use of these variables for the whole U.S. agricultural sector are available (USDA, Agricultural Statistics and USDA, 1986). Hence a method had to be designed to derive the use of these inputs in the U.S. crop sector. It is then assumed that the share of the expenses for petroleum products, electricity, and other input use in crop sector is proportional to the share of crop sector's cash receipts in total agricultural sectors' cash receipts (Thirtle 1985). For example, expenses for petroleum products in the crop sector are obtained by multiplying total expenses for petroleum products in the U.S. agriculture with crop sector's share in total cash receipts for the U.S. agriculture.

Producer price indexes are available for seed, lime, agricultural chemicals, energy, electricity. Price index of farm services is used as the price of "miscellaneous" input category. Using these prices and expenditure shares, a Divisia price index for the aggregate operating capital (OPCFP), was developed. An aggregate quantity index (OPCUS) was obtained by dividing the operating capital expenses by aggregate Divisia price index. Both the price and quantity indices are presented in Table A.1.

Labor Data on farm wages to labor and total farm labor use in the U.S. crop sector were collected from various issues of Agricultural Statistics. No distinction is made between hired labor and family labor. Both hired and family labor were aggregated into one category, total labor. Treating hired and family labor separately would have greatly increased the number of parameters to be estimated. These additional computational burdens are deemed to outweigh possible gains in insight in the technology. Moreover, several previous studies (for example: Weaver, 1983; Thirtle, 1985; Hertel and McKinze, 1986; and Moschini, 1988a) have demonstrated that total labor use can be aggregated into one category by assuming separability in hired and family labor. In the estimation, wage rate is used as the numeraire.

Fixed input: Durable farm machinery

The only fixed variable in the study is the total stock of durable farm machinery. Data on value of farm machinery are collected from various issues of Agricultural Statistics. Data are, however, available only at the aggregate level for the U.S. agricultural sector. Data on value of farm machinery used for the U.S. crop sector alone are not available. It is assumed that the share of the durable farm machinery used for crop sector in the total, is proportional to the share of crop sector's cash receipts in the total agricultural sector's cash receipts (Thirtle 1985).

Estimation

The complete list of equations to be estimated is:

$$(5.9) \quad Y_i = a_i + \sum_{j=1}^{16} b_{ij}\, EP_j + f_{i1}Z_1 + f_{i2}Z_2 \quad i = 1, 2, \ldots, 13$$

(5.10) $-X_i = a_i + \sum_{j=1}^{16} b_{ij} EP_j + f_{i1}Z_1 + f_{i2}Z_2 \quad i = 14, 15, 16$

(5.11) $-X_{17} = a_0 - \frac{1}{2}\sum_{i=1}^{16} \sum_{j=1}^{16} b_{ij} EP_i \cdot EP_j + c_1Z_1 + c_2Z_2$

(5.12) $PAR_i = 1\text{-}\exp[-\{a_{i1} \cdot (TP_i/FP_{it-1}) \cdot (1-SET_i-DIV_i) + a_{i2} \cdot (PDP_i/FP_{it-1}) \cdot DIV_i\}]$

i = wheat, rice, corn, other coarse grains, and cotton.

where,

Y_i = production of ith crop,

X_i = quantity of ith input used in the U.S. crop sector,

EP_i = expected price of ith netput (i=1,...,13 are outputs; i=14,...,17 are inputs),

Z_1 = quantity of fixed input (value of durable farm equipment),

Z_2 = time variable,

PAR_i = commodity program participation rate,

TP_i = target price of ith crop,

FP_i = farm price of ith crop,

SET_i = set-aside requirement for ith crop,

DIV_i = paid-diversion requirement for ith crop,

PDP_i = paid-diversion payment rate for ith crop,

and a_0, a_i, b_{ij}, c_k, d_{kl}, f_{ik}, a_{i2}, and a_{i2} are parameters estimated. Variables without a time subscript refer to the current period. A total of 22 equations (13 supply equations, 4 input demand equation, and 5 participation equations) are estimated

The profit function was not included in the system of equations to be estimated. At first glance, one is tempted to include the profit function on grounds that since the supply and input demand equations were derived from it, it surely constitutes additional information which should be brought to the estimation problem. This however is not the case. All information (that is, quantities and prices) needed to determine profit exactly is already included in the problem as it stands. Since profit in a time period is a linear combination of outputs and inputs, it can be shown that full covariance matrix of a system in which the profit function is included is singular (Shumway et al., 1987). The profit function is not included since it is just one of an infinite number of arbitrary linear combinations of the dependent variables which might be calculated, none of which adds any new information.

Estimation of participation rate equations

The participation rate equations (five of them, one each for wheat, rice, corn, other coarse grains, and cotton) in (5.12) are estimated separately from the rest of the equations. Data on the variables in equation (5.4) are available only for those years in the sample period during which government program existed. For example, in the case of wheat, voluntary acreage reduction programs are present only in 17 (1962-66, 1969-73, 1978-79, 1982-86) of the 37 sample period years (1950-1986). So equation (5.12) for wheat is relevant only for these 17 years. Hence the five equations in (5.12) are estimated independent of equations (5.9), (5.10), and (5.11).

Though equation (5.4) is non-linear in parameters, it can be easily transformed into a linear form:

(5.13) $RR_i = a_{i1} \cdot (TP_i/FP_{it-1}) \cdot (1-SET_i-DIV_i) + a_{i2} \cdot (PDP_i/FP_{it-1}) \cdot DIV_i$

where,

$i = 1, 2, 3, 4, 7$ (wheat, rice, corn, other coarse grains, and cotton), and

$RR_i = -\log(1-PAR_i)$.

Thus RR_i is an intrinsic transformation variable. Participation equations for each of the 5 crops are estimated by ordinary least squares in this linear form.

Estimation of output supply and input demand equations

Equations (5.9) through (5.11) are derived from the normalized quadratic profit function. In the empirical estimation, it is desirable to test and possibly maintain the properties of the profit function to ensure that there exists a genuine primal technology (see Chapter II). How these desirable properties of the profit function are maintained during the estimation is now discussed.

All prices on the right hand side of equations (5.9) through (5.11) are normalized by wage rate. Hence, these equations are homogeneous of degree zero in all prices. This of course holds, by design, with an arbitrary normalized profit function. Thus, the choice of the functional form ensured that the profit function is homogeneous of degree one in all output and input prices.

Symmetry of profit function in cross partials requires that the following condition must hold in equations (5.9) through (5.11):

(5.14) $b_{ij} = b_{ji} \quad . \quad \forall\ i,j \in [1, ..., 16]$

That is, equations (5.9) through (5.11) are to be estimated subject to the constraint (5.14) in order for the underlying profit function to be symmetric in cross partials. The symmetry condition in equation (5.14) is maintained in the present study during the estimation.

Monotonicity of the normalized quadratic profit function requires that predicted Y_i and X_i must be non-negative for all prices. In the present study monotonicity of the profit function is not explicitly imposed in the estimation. However, after the estimated parameters are obtained, this property is evaluated at each sample point.

Finally the estimated profit function is to be tested (and possibly imposed) for the convexity. The normalized profit function is convex if the matrix of b_{ij} coefficients in equations (5.9) through (5.11) is positive semi-definite. That is, convexity of profit function requires that, in equations (5.9) through (5.11) the following must hold:

(5.15) $[b_{ij}]$ is positive semi-definite

One obvious way to check for the convexity of profit function is to first estimate equations (5.9) through (5.11), get the estimated parameters b_{ij}*, and then check if $[b_{ij}]$ is indeed positive semi-definite. While this method enables us to check for the convexity after estimation, it does not provide a way to explicitly impose convexity. To impose (or to test statistically) the property of convexity, b_{ij} in equations (5.9) through (5.11) are to be reparameterized subject to (5.15).

Two conceptually manageable estimation (reparameterization) procedures for maintaining the necessary curvature constraints are: eigenvalue decomposition and Cholesky factorization. Both methods would of course yield the same $[b_{ij}]$ matrix. The method based on eigenvalue decomposition relies on the property that a real symmetric matrix is positive-semi definite if and only if all its eigenvalues are non-negative. In this method, matrix $[b_{ij}]$ is reparameterized, implied eigenvalues of the matrix are calculated and convexity if imposed by constraining the smallest eigenvalue to be non-negative. Though the method has no conceptual difficulties, it requires a great deal of computation compared to the Cholesky factorization. Hence in the present study Cholesky factorization is used to test and impose the convexity of profit function.

Cholesky factorization

Letting B be the 16x16 matrix of b_{ij} coefficients (from equations 5.9 through 5.11), the restricted profit function will be convex if B is positive semi-definite. Following Lau (1978), an imposition of global convexity of profit function is possible if B is estimated in Cholesky factorization. Lau (1978) has shown that almost every real symmetric matrix B can be represented in the nonlinear Cholesky factorization, B =

L•D•L', where L is a mxm unit lower triangular matrix ($L_{ii} = 1$, $L_{ij} = 0$ j>i) and D is diagonal matrix whose elements D_{ii} are referred to as Cholesky values. Note that there are m Cholesky values since D is a mxm matrix. Lau has further shown that every symmetric positive semi-definite matrix B has Cholesky factorization with unique L and D. Finally, matrix B will be positive semi-definite if and only if all Cholesky values are non-negative. This property is exploited in testing the convexity of the profit function. That is, the convexity of the profit function can be tested by simply testing for the non-negativeness of all the m Cholesky values. In other words convexity of profit function implies and is implied by $D_{ii} \geq 0 \; \forall$ i.

Similarly, convexity of the profit function can be imposed by replacing the matrix B in (5.9) through (5.11) by L•D•L' and constraining D such that $D_{ii} \geq 0 \; \forall$ i. In the present study convexity is tested as well as imposed in this manner. The complete mapping of matrices L•D•L' into B is given in Appendix B.

A few points are worth noting about estimating profit function via Cholesky factorization. First, symmetry condition has to be maintained to carry-out Cholesky factorization. Hence, tests for convexity are conditional on maintaining the symmetry of the profit function. Second, Cholesky factorization reparameterizes only the b_{ij} coefficients. Other coefficients are estimated as they appear in equations (5.9) through (5.11). Third, the total number of parameters to be estimated remains unchanged. After imposing symmetry, the original specification in equations (5.9) through (5.11) have 136 unique b_{ij} coefficients to be estimated. In the Cholesky factorization, instead of estimating these 136 b_{ij} coefficients directly, we would instead estimate 16 D_{ii} coefficients and 120 L_{ij} (L_{ij}, j<i) coefficients. Finally, since b_{ij} coefficients are now replaced by the non-linear functions of D_{ii} and L_{ij} coefficients, the estimated equations become non-linear in parameters (see Appendix B).

Because of shared parameters and because production decisions on one crop may be affected by or associated with decisions on another, contemporaneous correlation among product supply and input demand equations is likely. To account for this correlation properly, the thirteen output supply and three variable input demand equations were estimated simultaneously as a system using full information methods. Equations (5.9) through (5.11) form a set of seemingly unrelated equations.

Full information maximum likelihood estimator

The stochastic version of the nonlinear system of output supply and input demand equations can be written as:

$$\begin{aligned} y_1 &= f_1(X,\beta) + e_1 \\ y_2 &= f_2(X,\beta) + e_2 \\ &\vdots \\ y_M &= f_M(X,\beta) + e_M \end{aligned} \tag{5.16}$$

where, y and X represent endogenous and exogenous variables, respectively. Letting $e' = (e_1', e_2', \ldots, e_M')$, it is assumed that $E[ee'] = \Sigma\otimes I_T$, where Σ is an (MxM) covariance matrix whose (i,j) element is given by σ_{ij}, where $E[e_ie_j'] = \sigma_{ij}I_T$. The same matrix X and the same coefficient vector β appear in all equations to allow for the possibility that some explanatory variables, and some coefficients, can be common to more than one equation. Each equation can, of course, be a different nonlinear function of Z and β. With the additional assumption that the errors are normally distributed, the log-likelihood function for β and Σ can be written as

$$\begin{aligned} L(\beta,\Sigma) &= -\tfrac{1}{2}TM\cdot\log(2\pi) - \tfrac{1}{2}\log|\Sigma\otimes I_T| - \tfrac{1}{2}e'(\Sigma^{-1}\otimes I_T)e \\ &= -\tfrac{1}{2}TM\cdot\log(2\pi) - \tfrac{1}{2}T\cdot\log|\Sigma| - \tfrac{1}{2}tr[S\Sigma^{-1}] \end{aligned} \tag{5.17}$$

where, S is an (MxM) matrix with (i,j)th element equal to $e_i'e_j = [y_i-f_i(X,\beta)]'[y_i-f_i(X,\beta)]$. Nonlinear maximization of (5.17) with respect to all the elements in β and Σ would be a daunting task for the present case where M is relatively large at 17.

Fortunately, it is possible to obtain an analytical expression for the maximum likelihood estimator for Σ as a function of β and to therefore concentrate the likelihood function so that it is a function of β alone. In this regard, it is more convenient to differentiate $L(\beta,\Sigma)$ with respect to Σ^{-1} than Σ. It can be shown that (see Dhrymes 1978, Harvey 1985, and Judge et al. 1988),

(5.18) $\partial \log|\Sigma^{-1}|/\partial\Sigma^{-1} = \Sigma,$ and $\partial \mathrm{tr}[S\Sigma^{-1}]/\partial\Sigma^{-1} = S.$

Noting that $-(T/2)\log|\Sigma| = (T/2)\log|\Sigma^{-1}|$, and using the results in (5.18) we have

(5.19) $\partial L/\partial\Sigma^{-1} = (T/2)\Sigma - \frac{1}{2}S$

Setting this derivative equal to 0 and solving for Σ yields the estimator

(5.20) $\Sigma^* = S/T.$

Note that S is a function of β. Substituting (5.20) into (5.17) leads to the concentrated log-likelihood function

(5.21) $L^*(\beta) = \text{constant} - \frac{1}{2}T\log|S|$

Thus, the maximum likelihood estimator β^*, is that value of β that minimizes

(5.22) $$|S| = \begin{vmatrix} e_1'e_1 & \cdots & e_1'e_M \\ \vdots & & \\ e_M'e_1 & \cdots & e_M'e_M \end{vmatrix}$$

Thus, maximizing concentrated likelihood function is equivalent to minimizing the generalized sum of squares function. The maximum likelihood estimator for Σ is S/T, evaluated at β^*. Under the stated stochastic assumptions, the maximum likelihood estimators are consistent, asymptotically normal and asymptotically efficient. The parameter estimates are obtained using Davidon-Fletcher-Powell (DFP) algorithm (Powell, 1971) with numerical derivatives as implemented in GQ-OPT, version 4.02.

Summary

This chapter has described in detail the data and estimation procedures used to empirically implement the model outlined in Chapter IV. A number of specialized data are required to estimate the crop sector model consisting of 13 output supply and 4 input demand equations. Sources and formulae used for deriving data are presented in this chapter. A full information maximum likelihood procedure used for estimation is also outlined in this chapter.

CHAPTER VI. EMPIRICAL RESULTS

Previous Chapters have developed a specification of output supply and input demand equations with policy structure for U.S. crops. Empirical results for the estimated model are presented and appraised in this chapter.

Output Supply and Input Demand Equations

Maximum likelihood estimates of output supply and input demand equations maintaining symmetry, homogeneity and convexity are reported in Table 6.1. Note that all equations are originally linear in parameters. However, as shown in Chapter IV, parameters were estimated after a reparameterization imposing Cholesky factorization. Hence, the estimation process gives parameter estimates of Cholesky values (D_{ii}) and lower diagonal elements of matrix L. Estimated parameters of the price variables in Table 6.1 are calculated from a nonlinear combination of the estimated Cholesky factorization parameters. The standard errors of the b_{ij} parameters are computed by linearizing these nonlinear functions using a Taylor series expansion of the first order and then applying the standard results for variance and covariance of linear functions of random variables (Kmenta 1986, pages 486-487). Hence the t-ratios for estimated parameters of the price variables in Table 6.1 are only approximate.

Monotonicity of profit function ($\partial\Pi/\partial p_i \geq 0$) implies that the predicted output and (negative of) input quantities must be non-negative. Model simulation with estimated parameters indicated that monotonicity was not violated at the sample points. Note that normalized quadratic functional form maintains homogeneity in prices. Symmetry is maintained and not tested chiefly to save degrees of freedom in an already highly parameterized model[1]. Besides, when Cholesky factorization is used, maintaining symmetry is necessary in order to test for convexity.

Table 6.1. Maximum likelihood estimates of output supply and input demand equations maintaining symmetry and convexity[a]

$$
\begin{array}{llllll}
WHEPD_t = & -308.567 & + 0.245*VFM_t & + 0.162*YEAR_t & & \\
 & (3.857) & (8.030) & (258.059) & & \\
 & + 0.498*WHEEP_t & - 0.058*RICEP_t & + 0.022*COREP_t & + 1.243*OCGEP_t & \\
 & (56.380) & (1.989) & (55.725) & (64.806) & \\
 & - 0.031*SOYEP_t & + 0.351*HAYEP_t & - 0.501*COTEP_t & + 1.157*PNTEP_t & \\
 & (39.556) & (66.404) & (53.411) & (12.205) & \\
 & - 0.173*FXSEP_t & - 0.568*SUGEP_t & + 2.469*TOBEP_t & - 1.218*VEGEP_t & \\
 & (35.133) & (1.376) & (0.083) & (10.101) & \\
 & + 0.651*FUNEP_t & \multicolumn{3}{l}{- 0.013*RENT_t*[1+WHEPAR_t*WHEDIV_t/(1-WHESET_t)]} & \\
 & (7.580) & (1.555) & & & \\
 & - 0.047*FEREP_t & - 2.011*OPCEP_t & \multicolumn{2}{l}{- 1.648*WHEPAR_t*WHEDIV_t*WHEPDP_t} & \\
 & (0.499) & (0.060) & (1.497) & &
\end{array}
$$

R-square = 0.93

$$
\begin{array}{llllll}
RICPD_t = & -44.548 & + 0.002*VFM_t & + 0.023*YEAR_t & & \\
 & (4.455) & (0.763) & (44.640) & & \\
 & - 0.058*WHEEP_t & + 0.061*RICEP_t & + 0.080*COREP_t & - 0.245*OCGEP_t & \\
 & (1.989) & (5.318) & (7.205) & (9.005) & \\
 & - 0.029*SOYEP_t & - 0.059*HAYEP_t & - 0.019*COTEP_t & - 0.123*PNTEP_t & \\
 & (7.170) & (3.196) & (0.501) & (0.293) & \\
 & + 0.039*FXSEP_t & + 0.133*SUGEP_t & - 0.313*TOBEP_t & + 0.126*VEGEP_t & \\
 & (98.158) & (5.514) & (1.369) & (1.876) & \\
 & - 0.124*FUNEP_t & \multicolumn{3}{l}{+ 0.056*RENT_t*[1+RICPAR_t*RICDIV_t/(1-RICSET_t)]} & \\
 & (0.891) & (0.090) & & & \\
 & - 0.101*FEREP_t & + 0.300*OPCEP_t & & & \\
 & (2.291) & (32.963) & & &
\end{array}
$$

R-square = 0.84

[a]Variable explanations are given in Table 5.1. Figures in parentheses are absolute values of t-ratios.

Table 6.1. (continued)

$$
\begin{aligned}
CORPD_t = {} & \underset{(2764.614)}{-2764.651} \quad + \underset{(3.166)}{0.269*VFM_t} \quad + \underset{(1094.417)}{1.427*YEAR_t} \\
& + \underset{(55.725)}{0.022*WHEEP_t} + \underset{(7.205)}{0.080*RICEP_t} + \underset{(54.917)}{1.301*COREP_t} - \underset{(3.881)}{1.879*OCGEP_t} \\
& - \underset{(0.724)}{0.160*SOYEP_t} + \underset{(0.633)}{0.164*HAYEP_t} - \underset{(1.488)}{1.089*COTEP_t} - \underset{(0.736)}{2.437*PNTEP_t} \\
& + \underset{(2.273)}{0.294*FXSEP_t} - \underset{(6.165)}{0.210*SUGEP_t} + \underset{(0.032)}{3.161*TOBEP_t} - \underset{(12.226)}{0.449*VEGEP_t} \\
& - \underset{(1.847)}{0.309*FUNEP_t} - \underset{(6.758)}{0.042*RENT_t}*[1+CORPAR_t*CORDIV_t/(1-CORSET_t)] \\
& + \underset{(0.806)}{1.140*FEREP_t} - \underset{(1.564)}{0.195*OPCEP_t} - \underset{(35.966)}{36.338*CORPAR_t}*CORDIV_t*CORPDP_{tt}
\end{aligned}
$$

R-square = 0.94

$$
\begin{aligned}
OCGPD_t = {} & \underset{(656.831)}{-656.859} \quad - \underset{(5.433)}{0.202*VFM_t} \quad + \underset{(324.904)}{0.344*YEAR_t} \\
& + \underset{(64.806)}{1.243*WHEEP_t} - \underset{(9.005)}{0.245*RICEP_t} - \underset{(3.881)}{1.879*COREP_t} + \underset{(6.929)}{9.234*OCGEP_t} \\
& + \underset{(32.660)}{0.054*SOYEP_t} + \underset{(58.699)}{0.804*HAYEP_t} - \underset{(0.870)}{3.246*COTEP_t} + \underset{(5.000)}{2.447*PNTEP_t} \\
& - \underset{(72.735)}{2.961*FXSEP_t} - \underset{(15.963)}{1.168*SUGEP_t} + \underset{(0.315)}{3.398*TOBEP_t} - \underset{(2.355)}{7.623*VEGEP_t} \\
& + \underset{(3.519)}{2.802*FUNEP_t} + \underset{(2.109)}{0.066*RENT_t}*[1+OCGPAR_t*OCGDIV_t/(1-OCGSET_t)] \\
& - \underset{(158.382)}{2.117*FEREP_t} - \underset{(10.604)}{3.193*OPCEP_t} - \underset{(15.843)}{16.359*OCGPAR_t}*OCGDIV_t*OCGPDP_{tt}
\end{aligned}
$$

R-square = 0.57

Table 6.1. (continued)

$$
\begin{aligned}
SOYPD_t = & -1002.740 && + 0.041*VFM_t && + 0.514*YEAR_t \\
& (1002.664) && (1.338) && (593.920) \\
& - 0.031*WHEEP_t && - 0.029*RICEP_t && - 0.160*COREP_t && + 0.054*OCGEP_t \\
& (39.556) && (7.170) && (0.724) && (32.660) \\
& + 0.758*SOYEP_t && + 0.217*HAYEP_t && + 1.668*COTEP_t && + 2.305*PNTEP_t \\
& (17.144) && (113.234) && (0.253) && (7.586) \\
& - 0.226*FXSEP_t && + 0.206*SUGEP_t && - 0.227*TOBEP_t && + 1.268*VEGEP_t \\
& (33.704) && (6.280\ ) && (1.409) && (10.487) \\
& - 0.198*FUNEP_t && + 0.313*RENT_t \\
& (46.145) && (59.743) \\
& - 0.413*FEREP_t && - 2.396*OPCEP_t \\
& (24.366) && (1.384)
\end{aligned}
$$

R-square = 0.94

$$
\begin{aligned}
HAYPD_t = & -274.810 && - 0.001*VFM_t && + 0.145*YEAR_t \\
& (274.794) && (0.138) && (250.032) \\
& + 0.351*WHEEP_t && - 0.059*RICEP_t && + 0.164*COREP_t && + 0.804*OCGEP_t \\
& (66.404) && (3.196) && (0.633) && (58.699) \\
& + 0.217*SOYEP_t && + 0.508*HAYEP_t && - 0.082*COTEP_t && + 0.970*PNTEP_t \\
& (113.234) && (36.765) && (0.234) && (0.617) \\
& - 0.263*FXSEP_t && - 0.406*SUGEP_t && + 2.295*TOBEP_t && - 0.971*VEGEP_t \\
& (10.891) && (0.014) && (0.151) && (3.337) \\
& + 0.459*FUNEP_t && + 0.183*RENT_t \\
& (1.611) && (0.378) \\
& - 0.015*FEREP_t && - 2.230*OPCEP_t \\
& (0.146) && (2.928)
\end{aligned}
$$

R-square = 0.82

Table 6.1. (continued)

$$
\begin{aligned}
COTPD_t = {} & \underset{(2.944)}{-2506.362} \quad \underset{(1.485)}{-0.4510}*VFM_t + \underset{(275.835)}{1.293}*YEAR_t \\
& - \underset{(53.411)}{0.501}*WHEEP_t - \underset{(0.501)}{0.019}*RICEP_t - \underset{(1.488)}{1.089}*COREP_t - \underset{(0.870)}{3.246}*OCGEP_t \\
& + \underset{(0.253)}{1.668}*SOYEP_t - \underset{(0.234)}{0.082}*HAYEP_t + \underset{(0.859)}{138.351}*COTEP_t + \underset{(0.924)}{19.582}*PNTEP_t \\
& + \underset{(1.412)}{2.068}*FXSEP_t + \underset{(1.647)}{5.575}*SUGEP_t - \underset{(6.353)}{31.041}*TOBEP_t + \underset{(0.429)}{10.999}*VEGEP_t \\
& - \underset{(0.738)}{7.341}*FUNEP_t - \underset{(0.033)}{1.715}*RENT_t*[1+COTPAR_t*COTDIV_t/(1-COTSET_t)] \\
& - \underset{(1.376)}{5.595}*FEREP_t + \underset{(0.106)}{14.823}*OPCEP_t
\end{aligned}
$$

R-square = 0.33

$$
\begin{aligned}
PNTPD_t = {} & \underset{(1.944)}{-1696.629} + \underset{(0.287)}{0.021}*VFM_t + \underset{(477.513)}{0.874}*YEAR_t - \underset{(17.986))}{18.347}DUM80_t \\
& + \underset{(12.205)}{1.157}*WHEEP_t - \underset{(0.293)}{0.123}*RICEP_t - \underset{(0.736)}{2.437}*COREP_t + \underset{(5.000)}{2.447}*OCGEP_t \\
& + \underset{(7.586)}{2.305}*SOYEP_t + \underset{(0.617)}{0.970}*HAYEP_t + \underset{(0.924)}{19.582}*COTEP_t + \underset{(17.887)}{20.311}*PNTEP_t \\
& + \underset{(1.020)}{1.117}*FXSEP_t + \underset{(23.428)}{0.196}*SUGEP_t - \underset{(2.753)}{5.389}*TOBEP_t + \underset{(2.203)}{7.855}*VEGEP_t \\
& - \underset{(3.511\ )}{0.014}*FUNEP_t + \underset{(17.400)}{0.849}*RENT_t \\
& - \underset{(11.816)}{4.209}*FEREP_t \underset{(0.956)}{-11.258}*OPCEP_t
\end{aligned}
$$

R-square = 0.93

Table 6.1. (continued)

$$
\begin{aligned}
FLXPD_t = & -38.004 && + 0.052*VFM_t && + 0.019*YEAR_t && + 1.692*DUM79_t \\
& (37.915) && (2.736) && (33.368) && (4.187)) \\
& - 0.173*WHEEP_t && + 0.039*RICEP_t && + 0.294*COREP_t && - 2.961*OCGEP_t \\
& (35.133\ ) && (98.158) && (2.273) && (72.735) \\
& - 0.226*SOYEP_t && - 0.263*HAYEP_t && + 2.068*COTEP_t && + 1.117*PNTEP_t \\
& (33.704) && (10.891) && (1.412) && (1.020) \\
& + 1.855*FXSEP_t && + 0.097*SUGEP_t && - 1.723*TOBEP_t && + 3.541*VEGEP_t \\
& (2.985) && (37.330) && (21.446) && (11.259) \\
& - 0.737*FUNEP_t && - 0.282*RENT_t && && \\
& (3.942) && (30.310) && && \\
& + 0.326*FEREP_t && + 1.167*OPCEP_t && + 0.152*SFT77 && \\
& (0.684) && (11.758) && (0.273) &&
\end{aligned}
$$

R-square = 0.82

$$
\begin{aligned}
SUGPD_t = & -376.505 && - 0.115*VFM_t && + 0.194*YEAR_t && \\
& (376.456) && (8.909) && (313.486) && \\
& - 0.568*WHEEP_t && + 0.133*RICEP_t && - 0.210*COREP_t && - 1.168*OCGEP_t \\
& (1.376) && (5.514) && (6.165) && (15.963) \\
& + 0.206*SOYEP_t && - 0.406*HAYEP_t && + 5.575*COTEP_t && + 0.196*PNTEP_t \\
& (6.280) && (0.014) && (1.647) && (23.428) \\
& + 0.097*FXSEP_t && + 1.884*SUGEP_t && - 5.309*TOBEP_t && + 2.692*VEGEP_t \\
& (37.330) && (0.081) && (0.749) && (2.855) \\
& - 0.620*FUNEP_t && + 0.981*RENT_t && && \\
& (1.716) && (0.148) && && \\
& - 0.655*FEREP_t && + 1.601*OPCEP_t && && \\
& (2.780) && (2.985) && &&
\end{aligned}
$$

R-square = 0.87

Table 6.1. (continued)

$$TOBPD_t = \underset{(2.144)}{247.632} + \underset{(2.259)}{0.162}*VFM_t - \underset{(76.477)}{0.122}*YEAR_t$$

$$+ \underset{(0.083)}{2.469}*WHEEP_t - \underset{(1.369)}{0.313}*RICEP_t + \underset{(0.032)}{3.161}*COREP_t + \underset{(0.315)}{3.398}*OCGEP_t$$

$$- \underset{(1.409)}{0.227}*SOYEP_t + \underset{(0.151)}{2.295}*HAYEP_t - \underset{(6.353)}{31.041}*COTEP_t - \underset{(2.753)}{5.389}*PNTEP_t$$

$$- \underset{(21.446)}{1.723}*FXSEP_t - \underset{(0.749)}{5.309}*SUGEP_t + \underset{(0.887)}{35.736}*TOBEP_t - \underset{(2.059)}{10.732}*VEGEP_t$$

$$+ \underset{(0.283)}{4.539}*FUNEP_t - \underset{(5.946)}{0.746}*RENT_t$$

$$+ \underset{(3.455)}{6.241}*FEREP_t - \underset{(1.709)}{15.987}*OPCEP_t$$

R-square = 0.45

$$VEGPD_t = \underset{(6.119)}{-611.901} - \underset{(2.096)}{0.081}*VFM_t + \underset{(249.391)}{0.322}*YEAR_t$$

$$- \underset{(10.101)}{1.218}*WHEEP_t + \underset{(1.876)}{0.126}*RICEP_t - \underset{(12.226)}{0.449}*COREP_t - \underset{(2.355)}{7.623}*OCGEP_t$$

$$+ \underset{(10.487)}{1.268}*SOYEP_t - \underset{(3.337)}{0.971}*HAYEP_t + \underset{(0.429)}{10.999}*COTEP_t + \underset{(2.203)}{7.855}*PNTEP_t$$

$$+ \underset{(11.259)}{3.541}*FXSEP_t + \underset{(2.855)}{2.692}*SUGEP_t - \underset{(2.059)}{10.732}*TOBEP_t + \underset{(1.197)}{15.749}*VEGEP_t$$

$$- \underset{(7.396)}{2.888}*FUNEP_t + \underset{(5.961)}{0.882}*RENT_t$$

$$+ \underset{(0.647)}{0.211}*FEREP_t - \underset{(1.343)}{1.669}*OPCEP_t$$

R-square = 0.84

Table 6.1. (continued)

$$
\begin{aligned}
FUNPD_t = & \underset{(4.441)}{-479.578} \underset{(2.020)}{+ 0.076*VFM_t} \underset{(226.184)}{+ 0.250*YEAR_t} \\
& \underset{(7.580)}{+ 0.651*WHEEP_t} \underset{(0.891)}{- 0.124*RICEP_t} \underset{(1.847)}{- 0.309*COREP_t} \underset{(3.519)}{+ 2.802*OCGEP_t} \\
& \underset{(46.145)}{- 0.198*SOYEP_t} \underset{(1.611)}{+ 0.459*HAYEP_t} \underset{(0.738)}{- 7.341*COTEP_t} \underset{(3.511)}{- 0.014*PNTEP_t} \\
& \underset{(3.942)}{- 0.737*FXSEP_t} \underset{(1.716)}{- 0.620*SUGEP_t} \underset{(0.283)}{+ 4.539*TOBEP_t} \underset{(7.396)}{- 2.888*VEGEP_t} \\
& \underset{(0.187)}{+ 2.829*FUNEP_t} \underset{(9.414)}{+ 0.876*RENT_t} \\
& \underset{(4.451)}{+ 1.383*FEREP_t} \underset{(4.163)}{- 4.081*OPCEP_t}
\end{aligned}
$$

R-square = 0.90

$$
\begin{aligned}
LANUS_t = & \underset{(7.459))}{-71.594} \underset{(5.046)}{- 0.196*VFM_t} \underset{(19.137)}{+ 0.018*YEAR_t} \\
& \underset{(1.555)}{- 0.013*WHEEP_t} \underset{(0.090)}{+ 0.056*RICEP_t} \underset{(6.758)}{- 0.042*COREP_t} \underset{(2.109)}{+ 0.066*OCGEP_t} \\
& \underset{(59.743)}{+ 0.313*SOYEP_t} \underset{(0.378)}{+ 0.183*HAYEP_t} \underset{(0.033)}{- 1.715*COTEP_t} \underset{(17.400)}{+ 0.849*PNTEP_t} \\
& \underset{(30.310)}{- 0.282*FXSEP_t} \underset{(0.148)}{+ 0.981*SUGEP_t} \underset{(5.946)}{- 0.746*TOBEP_t} \underset{(5.961)}{+ 0.882*VEGEP_t} \\
& \underset{(9.414)}{+ 0.876*FUNEP_t} \underset{(2.095)}{+ 3.462*RENT_t} \\
& \underset{(3.077)}{+ 0.120*FEREP_t} \underset{(3.351)}{- 2.226*OPCEP_t}
\end{aligned}
$$

R-square = 0.57

Table 6.1. (continued)

$$
\begin{aligned}
FERUS_t = {} & \underset{(2.101)}{602.852} - \underset{(0.979)}{0.040*VFM_t} - \underset{(317.864)}{0.317*YEAR_t} \\
& - \underset{(0.499)}{0.047*WHEEP_t} - \underset{(2.291)}{0.101*RICEP_t} + \underset{(0.806)}{1.140*COREP_t} - \underset{(158.382)}{2.117*OCGEP_t} \\
& - \underset{(24.366)}{0.413*SOYEP_t} - \underset{(0.146)}{0.015*HAYEP_t} - \underset{(1.376)}{5.595*COTEP_t} - \underset{(11.816)}{4.209*PNTEP_t} \\
& + \underset{(0.684)}{0.326*FXSEP_t} - \underset{(2.780)}{0.655*SUGEP_t} + \underset{(3.455)}{6.241*TOBEP_t} + \underset{(0.647)}{0.211*VEGEP_t} \\
& + \underset{(4.451)}{1.383*FUNEP_t} + \underset{(3.077)}{0.120*RENT_t} \\
& + \underset{(5.846)}{5.932*FEREP_t} - \underset{(0.375)}{1.321*OPCEP_t}
\end{aligned}
$$

R-square = 0.93

$$
\begin{aligned}
OPCUS_t = {} & \underset{(3.801)}{-763.803} - \underset{(9.232)}{0.780*VFM_t} + \underset{(155.970)}{0.357*YEAR_t} \\
& - \underset{(0.060)}{2.011*WHEEP_t} + \underset{(32.963)}{0.300*RICEP_t} - \underset{(1.564)}{0.195*COREP_t} - \underset{(10.604)}{3.193*OCGEP_t} \\
& - \underset{(1.384)}{2.396*SOYEP_t} - \underset{(2.928)}{2.230*HAYEP_t} + \underset{(0.106)}{14.823*COTEP_t} - \underset{(0.956)}{11.258*PNTEP_t} \\
& + \underset{(11.758)}{1.167*FXSEP_t} + \underset{(2.985)}{1.601*SUGEP_t} - \underset{(1.709)}{15.987*TOBEP_t} - \underset{(1.343)}{1.669*VEGEP_t} \\
& - \underset{(4.163)}{4.081*FUNEP_t} - \underset{(3.351)}{2.226*RENT_t} \\
& - \underset{(0.375)}{1.321*FEREP_t} + \underset{(0.488)}{58.424*OPCEP_t}
\end{aligned}
$$

R-Square = 0.98

Table 6.1. (continued)

$$LABUS_t^{b} = \underset{(7.559)}{1558.480} + \underset{(8.350)}{0.297*VFM_t} - \underset{(7.578)}{0.799YEAR_t}$$

$$- (1/2) \sum_{i=1}^{16} \sum_{j=1}^{16} b_{ij}\, EP_i \cdot EP_j$$

R-Square = 0.97

System statistics:

Log-likelihood value: - 870.414 R^{*2} = 0.99[c]

[b]This equation was estimated conditional on the rest of the system.

[c]Baxter-Craigg R-square, see text for details.

Test for convexity of profit function

Since the model was estimated in Cholesky factorization a test for the convexity of the estimated profit function can be carried-out easily. Results in Table 6.1 are estimated maintaining convexity. However, to test for the convexity, unrestricted profit function (i.e., without imposing curvature constraints) had to be estimated. Given the reparameterization of $[b_{ij}]$ matrix by Cholesky factorization, convexity is satisfied if the estimated Cholesky values (D_{ii}) are all non-negative.

The parameters of Cholesky diagonal matrix D, directly estimated by the model are presented in Table 6.2. The estimates of the model without convexity restrictions are given under the column head, unrestricted model. Estimates indicate that 7 of the sixteen Cholesky values are negative, violating the convexity property. To assess this violation statistically, the null hypothesis of convexity is expressed as:

$$H_0: \quad D_{ii} \geq 0 \qquad i = 1, \ldots, 16,$$

which is tested against

$$H_A: \quad D_{ii} < 0 \qquad \text{for at least one } i.$$

Thus, H_0 will be violated if at least one D_{ii} is negative and statistically significant (Morey, 1986). A natural way to proceed is to use 16 one tailed tests. However in order to control for the overall level of significance, the level of significance of each one-tailed test must be scaled-down accordingly. In this situation, the Bonferroni t-statistics can be used to test for the significance of the individual D_{ii}. If the overall level of significance of the test is 0.05, having 16 simultaneous restrictions implies that the one-tailed critical value of the Bonferroni t-statistics for the individual t-ratios is given by the Student t-distribution at the 0.05/16 or 0.003125 significance level. The critical value is 2.734 for ∞ degrees of freedom. It follows that D_{33}, D_{44}, D_{66}, D_{88}, D_{99},

Table 6.2. Cholesky values (D_{ii}) of restricted and unrestricted models

i	-Unrestricted Model-[a] Estimate (D_{ii})	t-ratio	---Restricted Model--[b] Estimate (D_{ii})	t-ratio
1	0.275	9.306	0.498	56.380
2	0.062	4.070	0.055	78.226
3	-2.738	-7.662	1.176	7.435
4	-3.339	-10.417	3.245	1.947
5	0.522	11.673	0.724	27.644
6	-0.516	-7.612	0.133	23.863
7	162.667	1.627	130.321	1.550
8	-1.526	-3.346	0.324	11.199
9	-0.607	-13.605	0.269	41.799
10	1.718	15.240	0.875	18.158
11	15.405	17.005	5.948	1.811
12	-0.393	-2.329	1.422	2.168
13	-2.695	-10.143	1.070	4.366
14	1.442	4.610	2.004	5.014
15	5.915	7.541	1.326	4.232
16	35.564	3.556	33.954	1.424

[a]Convexity not imposed, symmetry imposed.

[b]Convexity and symmetry imposed.

D_{1313} are significantly negative and hence the null hypothesis of convexity is rejected at the 5% level of significance.

In spite of this difficulty the estimated profit function still provides a second order approximation to the data-generating variable profit function which is convex in prices (McKay et al., 1983). However a non-convex normalized profit function is inconsistent with profit maximization, the basic behavioral postulate of the theory of production. Furthermore, convexity is necessary for the profit function to be a dual to a well defined technology. The implication is, that any analysis with a non-convex profit function would be clouded. Hence, convexity of profit function is nevertheless imposed in the present study.

Convexity can be imposed by estimating the model subject to the restriction $D_{ii} \geq 0$, i = 1, ..., 16. This would make the estimation process a constrained optimization problem. Or equivalently, by suitable reparameterization of D_{ii} the estimation process can be altered to an unconstrained optimization. This latter approach is taken in the present study. Specifically, D_{ii} in the model are replaced by $D_{ii} = \exp(S_{ii})$. This restricts D_{ii}, the Cholesky values to be non-negative. Hence, Cholesky values obtained after this transformation satisfy the property of convexity. These Cholesky values along with their t-statistics are reported in Table 6.2 under the column head, "restricted model." 14 of the 16 estimated Cholesky parameters are significant at all conventional levels of significance. As result of the reparmeterization to restrict $D_{ii} \geq 0$, the value of log-likelihood decreased from -841.47 in unrestricted model to -870.41 in the restricted model[2].

Estimated model maintaining all theoretical restrictions fits the data reasonably well. R-square coefficients[3] ranged from 0.33 for cotton output supply equation to 0.98 for operating capital input demand equation (see Table 6.1). The median R-square is

0.84. R-square coefficients for cotton and tobacco were low at 0.33 and 0.45 respectively. Production levels for these crops have been erratic with large fluctuations perhaps explaining lack of better fit.

An overall indication of explanatory power of the entire system can be obtained from the "generalized R^2", R^{*2}, proposed by Baxter and Cragg (1970). The generalized R^2 is defined as:

$$R^{*2} = 1 - \exp[2(L_0 - L_{max})/T],$$

where, L_0 is the value of the log likelihood function when all parameters but intercepts were constrained to zero; L_{max} is the maximized value of the log-likelihood when all parameters are allowed to vary and T is the total number of parameters. The R^{*2} coefficient for the estimated system in Table 6.1 is 0.99, indicating that the overall goodness of fit is high.

Of a total of 194 parameters estimated, 128 are significant at 5% level of significance. 11 out of 16 outputs and inputs are significantly related to their respective own prices at the 5 percent level (Table 6.1); own price coefficients for cotton, sugarcane, vegetables, fruits and nuts, and operating capital are not significant at 5% level of significance. Own price effects of all other crops and inputs are significant at 5% level. Of course, by design (through the imposition of convexity of profit function), own price coefficients of outputs and inputs are positive indicating positively sloped product supply functions negatively sloped input demand functions.

All the 13 crops and 4 inputs had highly significant parameters for time trend. This implies that global indirect Hicks neutral technical progress in inputs and outputs can be ruled out (Chambers, 1988). It further signifies that production during the sample period has been characterized by technological change of some form.

Price elasticities of product supply and input demand

Output supply and input demand elasticities are presented in Table 6.3. Elasticity of ith product (Y_i)with respect to jth price (EP_j) is calculated by evaluating the following formulae at the sample means:

$$\epsilon_{ij} = b_{ij} \cdot EP_j/Y_i \qquad i, j = 1, ..., 16,$$

$$\epsilon_{i17} = - \sum_{k=1}^{16} b_{ik} \cdot EP_k/Y_i \qquad i = 1, ..., 16,$$

$$\epsilon_{17j} = - \sum_{k=1}^{16} b_{ik} \cdot EP_k \cdot EP_j/Y_{17} \qquad j = 1, ..., 16, \text{ and}$$

$$\epsilon_{1717} = \sum_{i=1}^{16} \sum_{j=1}^{16} b_{ij} \cdot EP_j \cdot EP_i/Y_{17}.$$

Note that homogeneity of output supply and input demand functions implies,

$$\epsilon_{i17} = - \sum_{k=1}^{16} \epsilon_{ik} \quad i = 1, ..., 17.$$

The elasticities in Table 6.3 correspond to the parameter estimates in Table 6.1 and are from the model maintaining homogeneity, symmetry, and convexity. Since elasticities are from a model preserving the curvature constraints, positive (negative) own-price elasticities of output supply (input demand) are ensured. However, curvature constraints do not impose restrictions on the signs of the cross price elasticities.

The own price elasticities of all outputs are less than unity, ranging from 0.028 for corn to 0.941 for tobacco. Own price elasticities for corn and wheat appear to be low at 0.028 and 0.050. Other own price output elasticities are around 0.4 to 0.5 and seem quite plausible. Cross price elasticities are, in general, small in magnitude. This implies that production of a crop is influenced the most by its own price, and prices of other crops have less impact. Own price elasticities for inputs range from -0.109 for land to -1.734 for labor. As expected land is the most inelastic input. Own price elasticities of operating capital and labor are the only elastic ones at -1.059 and -1.734 respectively.

Table 6.3 Price elasticities of product supply and input demand evaluated at sample means[a]

	Elasticity with respect to															
	WHEEP	RICEP	COREP	OCGEP	SOYEP	HAYEP	COTEP	PNTEP	FXSEP	SUGEP	TOBEP	VEGEP	FUNEP	RENT	FERFP	OPCFP	WAGE
WHEPD	0.050	-0.015	0.001	0.071	-0.004	0.044	-0.008	0.007	-0.008	-0.032	0.076	-0.042	0.037	-0.001	-0.004	-0.113	-0.060
RICPD	-0.104	0.280	0.093	-0.250	-0.068	-0.132	-0.005	-0.013	0.032	0.133	-0.173	0.078	-0.126	0.069	-0.155	0.302	0.040
CORPD	0.001	0.007	0.028	-0.035	-0.027	0.007	-0.006	-0.005	0.004	-0.004	0.032	-0.005	-0.006	-0.001	0.032	-0.004	-0.039
OCGPD	0.133	-0.066	-0.130	0.558	0.008	0.106	-0.053	0.015	-0.142	-0.069	0.111	-0.277	0.169	0.005	-0.192	-0.190	0.016
SOYPD	-0.005	-0.011	-0.058	0.004	0.146	0.039	0.038	0.020	-0.015	0.017	-0.010	0.063	-0.016	0.031	-0.051	-0.196	-0.039
HAYPD	0.046	-0.020	0.014	0.059	0.037	0.081	-0.002	0.007	-0.015	-0.029	0.092	-0.043	0.034	0.016	-0.002	-0.162	-0.114
COTPD	-0.014	-0.001	-0.019	-0.050	0.060	-0.003	0.583	0.031	0.025	0.084	-0.260	0.103	-0.113	-0.032	-0.130	0.226	-0.490
PNTPD	0.072	-0.019	-0.098	0.086	0.188	0.074	0.187	0.073	0.031	0.007	-0.102	0.166	0.000	0.036	-0.221	-0.389	-0.088
FXSPD	-0.186	0.107	0.205	-1.800	-0.319	-0.348	0.342	0.070	0.892	0.057	-0.567	1.297	-0.448	-0.207	0.297	0.700	-0.093
SUGPD	-0.194	0.115	-0.047	-0.226	0.092	-0.171	0.294	0.004	0.015	0.357	-0.556	0.313	-0.120	0.230	-0.190	0.305	-0.222
TOBPD	0.212	-0.068	0.176	0.165	-0.026	0.243	-0.411	-0.027	-0.066	-0.253	0.941	-0.314	0.221	-0.044	0.455	-0.767	-0.437
VEGPD	-0.097	0.025	-0.023	-0.343	0.133	-0.095	0.135	0.036	0.126	0.119	-0.261	0.427	-0.130	0.048	0.014	-0.074	-0.040
FUNPD	0.064	-0.031	-0.020	0.155	-0.026	0.055	-0.111	0.000	-0.032	-0.034	0.136	-0.096	0.157	0.059	0.115	-0.223	-0.169
LNDUS	0.001	-0.006	0.001	-0.002	-0.019	-0.010	0.012	-0.002	0.006	-0.025	0.011	-0.014	-0.023	-0.109	-0.005	0.057	0.128
FERUS	0.005	0.030	-0.087	0.140	0.063	0.002	0.101	0.029	-0.017	0.042	-0.223	-0.008	-0.091	-0.010	-0.588	0.086	0.526
OPCUS	0.065	-0.025	0.004	0.059	0.102	0.089	-0.074	0.021	-0.017	-0.029	0.159	0.018	0.075	0.050	0.036	-1.059	0.524
LABUS	0.044	-0.004	0.057	-0.006	0.026	0.080	0.205	0.006	0.003	0.027	0.116	0.013	0.072	0.141	0.284	0.670	-1.734

[a]Variable explanations are given in Table 5.1.

Note that these are elasticities with respect to aggregate expected price and not market price per se. Of course, these two would be the same in years with no government program. Also, it should be noted that elasticities reported in Table 6.3 are not total elasticities. Specifically, in program years, the elasticities in reported Table 6.3 do not capture the effects of price changes on participation rates. For example, a change in market price FP_i has two distinct effects on the production of ith crop; a direct effect measured by b_{ij} (and hence by ϵ_{ij}) and an indirect effect via PAR_i equation. Only the direct effects are captured in the elasticities in Table 6.3. Other studies fail to make this important distinction. This feature of the specification should be kept in mind in making comparisons with other studies.

Care should be deployed in comparing the elasticities with the ones from other studies. There are few comparable studies that provide a rich collections of elasticities at this level of output disaggregation. Different commodity classification, rigorous maintenance of theoretical restrictions and structural policy implementation in the present study sets the present study apart and makes the comparison difficult. Nevertheless, comparing with other studies places the current elasticity estimates in perspective. Though the own price elasticities for corn and wheat are some what smaller, the elasticities, in general compare with the ones from Shumway et al. (1988). However many of the cross price elasticities, though significant, are small in magnitude.

Nested model

The general multioutput model allows for the interaction among all outputs, thus, allowing production of a crop to respond to changes in prices of all other crops. While this is a logical implication of a multioutput technology in general, it is possible that output of certain products may not depend on all prices. In the U.S. crops are grown on geographically different areas and it is likely that some non-jointness in production to exist among certain crops. To pursue non-jointness, the model is reestimated letting some b_{ij} be zero. This model is referred to as "nested model". Elasticity estimates from the nested model maintaining symmetry and convexity are reported in Table 6.4. It is hypothesized that cross price elasticity estimates from the nested model would be bigger in magnitude since. Surprisingly, however the elasticities from the nested model (Table 6.4) are similar to the elasticities from the full model (Table 6.3). As Table 6.4 indicates, 61 b_{ij} coefficients are restricted to zero in the estimation of the nested model; only 34 cross price elasticities among outputs are estimated.

To verify the validity of the nested model formally, a log-likelihood ratio test is employed. The likelihood ratio test statistics is determined by:

$$-2 \log \lambda = - 2 \cdot [\log L(\underline{\theta}) - \log L(\theta^*)],$$

where $\underline{\theta}$ represents the restricted maximum likelihood estimates of the parameter vector θ and θ^* denotes the corresponding unrestricted maximum likelihood estimates. Asymptotically, $-2 \log \lambda$ is distributed as chi-square with J degree of freedom (J equaling the number of independent restrictions being tested) under the null hypothesis that , $\underline{\theta}$ is true. As a result of letting some b_{ij} to zero the value of log-likelihood function reduced from -870.41 (in the full model) to -925.85. The calculated chi-square 110.88 is higher than the critical value 80.24 for 5% level of significance and 61 degrees of freedom implying that the nested model is to be rejected in favor of the full model. The reason for rejecting the nested model is that too many significant b_{ij} coefficients are set to zero. Perhaps by a more careful selection of restrictions, cross price elasticities might be made more plausible. Also, it might be beneficial to examine these elasticities when convexity is not imposed.

Table 6.4. Nested model: Price elasticities of product supply and input demand evaluated at sample means[a]

	- Elasticity with respect to																-
	WHEEP	RICEP	COREP	OCGEP	SOYEP	HAYEP	COTEP	PNTEP	FXSEP	SUGEP	TOBEP	VEGEP	FUNEP	RENT	FERFP	OPCFP	WAGE
WHEPD	0.126	[a]		0.001		0.002			-0.001					0.007	-0.008	-0.022	-0.104
RICPD		0.159			0.042		-0.009							-0.024	-0.030	-0.036	-0.102
CORPD			0.052	-0.015	-0.016		0.001	-0.001						-0.002	0.002	0.019	-0.056
OCGPD	0.001		-0.013	0.023	0.001	-0.001				-0.001				0.001	0.016	-0.017	-0.024
SOYPD		0.007	-0.036	0.001	0.155		-0.001	0.001		-0.001				-0.025	-0.010	0.022	-0.113
HAYPD	0.002			-0.001		0.090								0.005	0.001	-0.017	-0.081
COTPD		-0.002	0.001		-0.001		0.545							-0.030	-0.102	0.223	-0.635
PNTPD			-0.003		0.003			0.003						0.003	-0.009	0.017	-0.014
FXSPD	-0.001								0.537	-0.169				0.112	0.108	0.042	-0.630
SUGPD				-0.001	-0.001				-0.043	0.269				-0.017	-0.039	-0.011	-0.158
TOBPD											0.495			0.053	0.217	-0.365	-0.400
VEGPD												0.144	-0.046	0.018	-0.015	0.032	-0.132
FUNPD												-0.034	0.132	0.014	0.015	-0.013	-0.114
LNDUS	-0.004	0.002	0.003	0.001	0.015	-0.003	0.012	0.001	-0.003	0.002	-0.013	-0.005	-0.005	-0.070	-0.004	-0.003	0.077
FERUS	0.011	0.006	-0.007	-0.012	0.012	-0.002	0.079	0.001	-0.006	0.009	-0.107	0.009	-0.012	-0.007	-0.499	0.169	0.355
OPCUS	0.013	0.003	-0.022	0.005	-0.011	0.009	-0.073	-0.001	-0.001	0.001	0.076	-0.008	0.004	-0.003	0.071	-0.813	0.749
LABUS	0.077	0.011	0.081	0.010	0.075	0.057	0.266	0.001	0.020	0.019	0.106	0.042	0.049	0.086	0.191	0.957	-2.048

[a]Variable explanations are given in Table 5.1.

[b]Restricted to zero in the estimation. A total of 61 b_{ij} parameters have been set to zero in the estimation of the nested model.

Equations for Program Participation Rate

Estimated equations for program participation rates are presented in Table 6.5. These equations were estimated for wheat, rice, corn, other coarse grains, and cotton. Note that by definition, the left hand side variables (WHEPAR, RICPAR, CORPAR, OCGPAR, COTPAR) are bounded by zero and one. The functional form used complies with this restriction. In particular, the participation rate approaches one as target price or diversion payment approaches infinity. Since observations from only those years which have a commodity program are used in the estimation, the sample size varied from equation to equation (see Table 6.5). The sample size for wheat is 17 while for corn and other coarse grains it was 20. The voluntary programs for rice and cotton, as modeled, started with the 1981 Farm Bill. Hence, the sample size to estimate the participation rate equations for rice and cotton is precariously low at 5. In view of these few observations, one is perhaps better off not estimating program participation rate equations for rice and cotton. But for completeness these equations were nevertheless estimated. Parameters estimated from these two equations should be judged accordingly.

Results in Table 6.5 indicate that the positive signs of all the estimated parameters are consistent with a priori expectations. The positive sign of the estimated parameters indicates that the postulated variables in participation rate equations behave in a manner consistent with the theoretical model. Calculated t-values of the estimated parameters ranged from 2.467 to 14.046. All parameters are significant at 5% level of significance.

Elasticities of program participation rate for the five crops with respect to all the right hand side variables are presented in Table 6.6. Equations (4.5a) through (4.5d) indicate that elasticity expressions for the participation rate depend on the level of policy variables. In other words, elasticities derived are not constant. To facilitate

Table 6.5 Ordinary least squares estimates of commodity program partcipation rate equations[a]

Wheat:[b]

$$WHEPAR_t = 1 - \exp(WHERR_t)$$

$$WHERR_t = \underset{(4.747)}{1.144} \cdot (WHETP_t/WHEFP_{t-1}) \cdot (1 - WHESET_t - WHEDIV_t) + \underset{(3.157)}{9.731} \cdot (WHEPDP_t/WHEFP_{t-1}) \cdot WHEDIV_t$$

R-square = 0.459

Rice:[c]

$$RICPAR_t = 1 - \exp(RICRR_t)$$

$$RICRR_t = \underset{(14.046)}{2.028} \cdot (RICTP_t/RICFP_{t-1}) \cdot (1 - RICSET_t - RICDIV_t) + \underset{(8.192)}{9.490} \cdot (RICPDP_t/RICFP_{t-1}) \cdot RICDIV_t$$

R-square = 0.928

Corn:[d]

$$CORPAR_t = 1 - \exp(CORRR_t)$$

$$CORRR_t = \underset{(7.576)}{0.816} \cdot (CORTP_t/CORFP_{t-1}) \cdot (1 - CORSET_t - CORDIV_t) + \underset{(3.341)}{1.890} \cdot (CORPDP_t/CORFP_{t-1}) \cdot CORDIV_t$$

R-square = 0.031

[a]See Table 5.1 for variable explanations. Figures in parentheses are t-ratios.

[b]Years: 1962-66, 1969-73, 1978-79, 1982-86; sample size = 17.

[c]Years: 1982-1986; sample size = 5.

[d]Years: 1961-1973, 1978-79, 1982-86; sample size = 20.

Table 6.5 (continued)

<u>Other Coarse Grains:</u>[d]

$$OCGPAR_t = 1 - \exp(OCGRR_t)$$

$$OCGRR_t = \underset{(6.426)}{0.900} \cdot (OCGTP_t/OCGFP_{t-1}) \cdot (1 - OCGSET_t - OCGDIV_t)$$

$$+ \underset{(3.075)}{2.386} \cdot (OCGPDP_t/OCGFP_{t-1}) \cdot OCGDIV_t$$

R-square = 0.369

<u>Cotton:</u>[c]

$$COTPAR_t = 1 - \exp(COTRR_t)$$

$$COTRR_t = \underset{(6.437)}{1.729} \cdot (COTTP_t/COTFP_{t-1}) \cdot (1 - COTSET_t - COTDIV_t)$$

$$+ \underset{(2.467)}{5.647} \cdot (COTPDP_t/COTFP_{t-1}) \cdot COTDIV_t$$

R-square = 0.435

Table 6.6 Estimated elasticities of participation rates[a]

Variable	TP	PDP	SET	DIV	FP
	Elasticity with respect to				
WHEPAR	0.300	0.133	-0.038	0.095	-0.433
RICPAR	0.231	0.056	-0.029	0.027	-0.287
CORPAR	0.434	0.052	-0.054	-0.002	-0.487
OCGPAR	0.431	0.060	-0.054	0.006	-0.490
COTPAR	0.317	0.054	-0.040	0.014	-0.371

[a]All elasticities are evaluated at $TP/FP_{t-1} = 1.2$, $SET = 0.1$, $PDP/FP_{t-1} = 0.5$, $DIV = 0.1$, and $PAR = 0.75$. See text for variable definitions.

across crop comparisons, all elasticities of program participation rates for all crops are evaluated at: TP_i/FP_{it-1} =1.2, PDP_i/FP_{t-1} = 0.5, SET_i = 0.1, DIV_i = 0.1, and PAR_i = 0.75. Elasticities in Table 6.6 are fairly uniform across the five crops. Elasticities with respect to target price ranged from 0.231 for rice to 0.434 for corn and seem quite plausible. As expected, in absolute values, elasticity with respect to target price is higher than the elasticity with respect to set-aside requirements. This is true for all 5 crops. Elasticity with respect to paid-diversion requirements were more diverse across crops. Specifically, this elasticity is negative (but small at -0.002) for corn while positive for other crops. Note that both signs are admissible under the specification (see equation (4.5d)). Overall the estimated program participation rate equations are satisfactory and encouraging. They indicated that a structural policy implementation can be fruitfully and meaningfully applied for the commodity programs in the U.S. In general the estimates of the participation rate equations represent a significant improvement over previous work (de Gorter and Paddock 1985, and Skold and Westhoff 1988).

Summary

In summary, the empirical results presented in this chapter are encouraging. Results from the empirical work supported the findings of the theoretical model. Own price elasticity estimates from output supply and input demand equation are reasonable though the cross price elasticities are small in magnitude. Parameter estimates from the program participation rate equations are significant and are consistent in sign with a priori expectations. In general empirical results indicated that microeconomic theory of competitive firm behavior can be successfully integrated with a structural policy implementation in the U.S. agricultural sector.

End Notes

1. To estimate the model without symmetry would require estimating an additional 120 parameters.

2. Several different starting values for parameters were tried in the estimation process. When estimating restricted model (imposing convexity), one particular set of starting values included setting D_{33}, D_{44}, D_{66}, D_{88}, D_{99}, and D_{1313} to zero.

3. R-Square coefficient for each equation is defined as the squared correlation between the actual and the predicted values of the left hand side variable (Maddala 1988, Page 307).

CHAPTER VII. POLICY ANALYSIS

The model structure presented in Chapter IV provides a rich framework for conducting policy analysis. Recall that a number of comparative static results derived in Chapters III and IV could not be signed in general. For instance, the effects of the target price and acreage restriction parameters on industry output could not be clearly established. The estimated output supply and input demand equations with their policy structure reported in Chapter VI can now be used to evaluate empirically the comparative static results by way of policy simulation exercises. In this chapter selected exogenous and predetermined policy variables are parametrically altered and inferences are made about the potential impacts of these variables on production, input use and program participation rate.

Historical Simulation

A criterion used to evaluate a model is the fit of the individual variables in a simulation context. One way to test the performance of the model is conduct an historical simulation (i.e., simulation through the estimated period) and examine how closely each endogenous variable tracks the corresponding historical data series (Pindyck and Rubinfeld, 1981). Good simulation performance gives added confidence to the policy analysis done with the model it.

The simulation uses the estimates of 13 output supply equations, 4 input demand equations (Table 6.1) and the five participation rate equations (Table 6.5). In addition, definitional identities (4.7b), (4.7c), (4.7d), (4.7f), (4.8a), and (4.8b) are used to generate aggregate expected price. Note however that the market price is exogenous. The historical simulation uses the sample data from 1951-1986 period. The performance of each equation is evaluated by using mean absolute percent error (MAPE) and Theil's forecast error measures.

MAPE measures the average of the absolute difference between the historical series (A_t) and simulated series (S_t) relative to the historical series and is given by:

$$MAPE = (1/N) \sum_{t=1}^{N} |(A_t - S_t)| / A_t,$$

where, N is the number of periods of simulation. The MAPE implies a linear loss function; large MAPE indicating poor simulation performance. Theil's forecast error decomposition measures are given by (Pindyck and Rubinfeld, 1981):

$$Um = N \cdot (\mu_s - \mu_a) / \sum (A_t - S_t)^2,$$

$$Us = N \cdot (\sigma_s - \sigma_a) / \sum (A_t - S_t)^2, \text{ and}$$

$$Uc = 2N \cdot (1 - \rho) \cdot (\sigma_s - \sigma_a) / \sum (A_t - S_t)^2,$$

where, μ_s, μ_a, σ_s, σ_a are the means and standard deviations of the series A_t and S_t, respectively, and ρ is their correlation coefficient. The proportions Um, Us, and Uc are called bias, the variance, and the covariance proportions, respectively. Note that Um + Us + Uc = 1, hence they are called proportions. The bias proportion Um is an indication of systematic error, since it measures the extent to which the average values of the simulated and actual series deviate from each other. The variance proportion Us indicates the ability of the model to replicate the degree of variability in the variable of interest. Finally, the covariance proportion measures unsystematic error. In a perfect fit, Um = Us = 0, and Uc = 1.

Mean absolute percent errors and Theil's error decomposition proportions are reported in Table 7.1. MAPE for all equations except flaxseed and sunflower production are below 15 percent. MAPE for FXSPD is relatively higher at 24.84 percent. Production of flaxseed and sunflower was erratic during the sample period and a good fit is difficult to obtain. The bias proportion and variance proportions (Um + Uc) are low relative to the covariance proportions (Uc). None of the bias proportions exceeded 0.08 indicating there is little systematic bias in the model. The variance proportion for

Table 7.1. Simulation statistics of the estimated model[a]

Equation	MAPE[b]	---Theils forecast statistics--- Bias (Um)	Variance (Us)	Covariance (Uc)
Output supply equations:				
WHEPD	7.97	0.002	0.031	0.968
RICPD	14.02	0.002	0.010	0.988
CORPD	6.65	0.001	0.014	0.985
OCGPD	11.02	0.000	0.014	0.986
SOYPD	10.58	0.004	0.001	0.995
HAYPD	3.42	0.000	0.001	0.999
COTPD	13.70	0.005	0.209	0.786
PNTPD	9.14	0.005	0.016	0.979
FXSPD	24.84	0.011	0.078	0.911
SUGPD	6.59	0.006	0.004	0.990
TOBPD	9.53	0.000	0.085	0.915
VEGPD	4.27	0.000	0.025	0.975
FUNPD	5.81	0.006	0.008	0.986
Input demand equations:				
LNDUS	2.54	0.003	0.134	0.863
FERUS	10.87	0.001	0.002	0.997
OPCUS	3.51	0.004	0.020	0.975
LABUS	8.84	0.000	0.038	0.962
Participation rate equations:				
WHEPAR	10.542	0.035	0.133	0.832
RICPAR	0.332	0.083	0.232	0.685
CORPAR	14.166	0.011	0.063	0.926
OCGPAR	13.602	0.027	0.055	0.918
COTPAR	0.933	0.073	0.143	0.784

[a]See text for variable definitions.

[b]Mean absolute percent error.

cotton production is higher at 0.209; the simulated series is smoother than the actual data.

In general, the simulation statistics reported in Table 7.1 indicate that the estimated model effectively simulates historical production, input use level, and program participation rates. These model validation measures lend further support to the conclusion that the estimated structure adequately reflects the production technology in the U.S. crop sector.

Scenario Analysis

Two policy scenarios are evaluated using the estimated model reported in Chapter VI. These scenarios are: (1) increased target price, and (2) increased set-aside requirements. Results are prepared relative to a baseline scenario which embedded historical agricultural policies as reflected by the model structure and by the data in Appendix A used for exogenous variables. The simulation period used for policy evaluations is 1961-1986. The results reported here are obtained from deterministic simulations.

Target prices

The results of a 10 percent increase in the target prices of wheat, rice, corn, other coarse grains, and cotton over the periods 1960-1986 are reported in Tables 7.2 and 7.3. Target prices are increased by 10 percent over the actual values only in the years a target price existed historically. To facilitate interpretation, results are reported in percent changes over the baserun.

An increase in target price, as expected, results in an increase in program participation rate (Table 7.2) for all the five crop. Program participation rates for corn and other coarse grains increased the most, by an average of about 4.5 percent (over the baseline) during the program years. Using a simple linear model, Westhoff and Skold

Table 7.2. Percent changes in program participation rates under a 10 percent increase in target prices[a]

YEAR	WHEPAR	RICPAR	CORPAR	OCGPAR	COTPAR
1961	0.000[b]	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	4.292	4.081	0.000
1964	4.094	0.000	3.022	2.524	0.000
1965	3.166	0.000	3.188	2.817	0.000
1966	2.776	0.000	3.927	3.824	0.000
1967	0.000	0.000	5.068	5.913	0.000
1968	0.000	0.000	3.795	4.107	0.000
1969	1.810	0.000	3.744	4.039	0.000
1970	2.292	0.000	4.226	4.313	0.000
1971	6.666	0.000	7.124	6.847	0.000
1972	0.000	0.000	5.520	5.370	0.000
1973	1.335	0.000	6.519	6.404	0.000
1974	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000
1978	4.172	0.000	5.068	5.383	0.000
1979	5.302	0.000	6.128	5.676	0.000
1980	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000
1982	5.305	3.107	6.259	6.342	2.857
1983	2.507	0.302	4.847	4.709	0.869
1984	1.695	3.083	6.700	6.344	3.602
1985	1.716	1.748	6.095	6.040	2.571
1986	3.330	2.178	5.735	5.610	3.092
Average	1.776	0.401	3.510	3.475	0.500
	(2.716)[c]	(2.084)	(4.563)	(4.517)	(2.598)

[a]See Table 5.1 for variable definitions.

[b]In this year, there is no target price in the baserun. Hence, target price is not changed.

[c]Figures in parentheses are average percent changes over program years only.

Table 7.3. Percent changes in production and input demand under a 10 percent increase in target price[a]

YEAR	WHEPD	RICPD	CORPD	OCGPD	SOYPD	HAYPD	COTPD	PNTPD	FXSPD
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.46	-0.92	-0.33	1.59	-0.14	0.43	-0.36	-0.32	-1.11
1964	1.12	-2.95	-0.52	3.88	-0.17	0.97	-0.55	0.58	-2.67
1965	0.87	-1.90	-0.36	1.87	-0.18	0.78	-0.41	0.39	-1.86
1966	1.17	-2.93	-0.32	3.18	-0.16	1.00	-0.54	0.84	-1.65
1967	0.35	-0.73	-0.23	1.39	-0.07	0.33	-0.37	-0.16	-0.93
1968	0.38	-0.71	-0.31	1.45	-0.07	0.37	-0.36	-0.17	-0.53
1969	0.97	-2.16	-0.31	2.51	-0.12	0.86	-0.57	0.66	0.13
1970	0.88	-1.96	-0.27	2.35	-0.10	0.79	-0.52	0.62	-4.25
1971	0.69	-1.56	-0.02	2.08	-0.07	0.62	-0.44	0.46	0.15
1972	0.88	-1.98	-0.14	2.59	-0.09	0.79	-0.52	0.48	0.16
1973	0.88	-2.15	-0.01	2.81	-0.09	0.84	-0.58	0.59	0.20
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.51	-1.38	-0.30	2.96	-0.04	0.60	-0.48	0.36	-0.23
1979	0.40	-1.21	-0.16	2.75	-0.03	0.49	-0.40	0.34	-0.08
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.17	0.66	0.02	0.81	0.07	0.26	4.21	0.89	-0.02
1983	0.25	0.42	-0.34	1.28	0.07	0.38	4.24	1.05	-0.08
1984	0.18	0.46	-0.02	1.14	0.08	0.26	3.64	1.01	-0.04
1985	0.25	0.41	-0.01	1.46	0.07	0.37	3.69	0.96	-0.07
1986	0.28	0.36	-0.04	1.34	0.06	0.37	3.24	0.88	-0.10
Average	0.41	-0.78	-0.14	1.44	-0.04	0.40	0.50	0.36	-0.44

[a]See Table 5.1 for variable definitions.

Table 7.3. (continued)

YEAR	SUGPD	TOBPD	VEGPD	FUNPD	LNDUS	FERUS	OPCUS	LABUS
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	-1.64	2.04	-1.88	0.71	0.00	0.11	0.41	-0.29
1964	-3.79	4.22	-3.25	1.57	0.00	0.43	1.19	-0.16
1965	-3.20	3.66	-2.13	1.04	0.01	-0.07	0.98	-0.06
1966	-4.23	4.22	-2.90	1.53	0.01	0.27	1.23	0.04
1967	-1.26	1.45	-1.43	0.56	-0.00	0.14	0.27	-0.24
1968	-1.16	2.09	-1.48	0.63	-0.00	0.13	0.30	-0.31
1969	-3.37	4.03	-2.57	1.26	0.01	0.19	0.97	0.01
1970	-3.04	3.69	-2.28	1.16	0.01	0.19	0.85	0.02
1971	-2.30	2.90	-1.89	0.94	0.00	0.20	0.62	0.12
1972	-2.87	3.73	-2.45	1.19	0.00	0.23	0.83	0.03
1973	-3.45	3.65	-2.56	1.21	0.01	0.23	0.87	0.18
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	-2.56	2.96	-2.17	0.91	-0.00	0.30	0.53	-0.17
1979	-2.05	2.38	-1.80	0.75	-0.00	0.31	0.41	-0.08
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.07	-1.19	-0.30	-0.23	0.04	0.56	-0.13	2.78
1983	0.63	-0.76	-0.86	-0.04	0.04	0.73	-0.04	2.62
1984	0.89	-1.51	-0.32	-0.16	0.04	0.65	-0.09	2.44
1985	0.55	-0.78	-0.79	-0.05	0.04	0.65	-0.04	2.42
1986	0.38	-0.73	-0.86	-0.01	0.04	0.62	-0.03	2.03
Average	-1.21	1.39	-1.23	0.50	0.01	0.23	0.35	0.44

(1987) obtained a 5.53 percent drop in corn participation rate for a 10 percent drop in target price. With an average increase of 2.1 percent, program participation rates for rice increased the least among the five crops. In general, the changes in participation rates reflect the elasticities in Table 6.6.

A ten percent increase in target prices has a mixed effect on production and input use (Table 7.3). Note that results presented in Table 7.3 are due to a *simultaneous* increase in the target prices for wheat, rice, corn, other coarse grains, and cotton. Production of wheat and other coarse grains increased in all years during the period 1961-86 by an average of 0.41 and 1.44 percent respectively. During the same period corn production decreased by an average of 0.14 percent. However, in the year 1982, corn production increased by about 0.02 percent. Similarly, rice production fluctuated from a decrease of 2.95 percent in year 1964 to an increase of 0.66 percent in 0.66. Production other crops exhibited similar fluctuations. Thus, the overall effect of a simultaneous increase in all target prices for crop production is mixed. Recall that the comparative static results in Chapter IV indicated that the overall effect of a change in the target price is ambiguous and results reported in Table 7.3 seem to confirm this argument.

Set-aside requirements

In this scenario, set-aside requirements (SET_i) for wheat, rice, corn, other coarse grains, and cotton are increased by 100 percent over historical levels; for example, set-aside parameter for corn is increased from 0.10 to 0.20 in the year 1982. That is, during the simulation period, new set-aside requirements are obtained by simply multiplying the historical set-aside parameter by 2.0. This implies, that set-aside requirements are changed (doubled) only in those years in which they existed.

Effects of 100 percent increase in set-aside parameters on program participation rates are reported in Table 7.4. Program participation rates decreased for all the five crops though the magnitude varied from year to year and from crop to crop depending on level of other program parameters. For example, as a result of doubling set-aside requirement, program participation rate for corn in year 1986 decreased by about 12.5 percent (from 80.7 to 70.6). Changes in program participation rates are fairly uniform for all crops, around 8 percent, reflective of the elasticities in Table 6.6.

Doubling of set-aside requirements had less effect on production and input use (see Table 7.5). Note that set-aside requirements are changed only in years after 1977. To reflect this feature of the impacts, separate averages over the period 1978-86 is provided at the bottom of the Table 7.5. Though the magnitude is small, it is interesting to note that the direction of change in production is not always the same. In fact, except for peanuts, change in production of all other crops did not have an uniform direction - there were years in which production increased and years in which production decreased. For example, as a result of increase in set-aside requirements, production of other coarse grains decreased in years 1978, 1979, and 1986, while increasing in years 1982 through 1985. This lack of conformity in the direction of effect of an increase in set-aside parameter is not unexpected.

Recall from the comparative static results in Chapter IV, that an increase in set-aside parameter has two distinct effects - first by changing the aggregate expected price via a change in the participation rate, and second by changing the effective rental price of land - acting (possibly) in opposite directions. The overall effect depends on the exact level of policy variables and parameters. In fact, because of these off-setting influences, the total effect on the production is small. This important distinction is lost in reduced form representations of policy variables. For example, in Shumway et al.

Table 7.4. Percent changes in program participation rates under a 100 percent increase in set-aside requirements[a]

YEAR	WHEPAR	RICPAR	CORPAR	OCGPAR	COTPAR
1961	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000
1966	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000
1978	-10.254	0.000	-5.391	-6.132	0.000
1979	-12.503	0.000	-6.482	-7.893	0.000
1980	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000
1982	-10.814	-13.717	-7.488	-7.805	-5.178
1983	-7.604	-1.782	-9.332	-7.320	-4.110
1984	-5.817	-25.075	-8.105	-7.964	-14.026
1985	-6.104	-12.893	-7.342	-7.301	-9.063
1986	13.391	-26.691	-12.540	-14.483	-14.181
Average	-2.557	-3.083	-2.180	-2.265	-1.791
	(-9.498)	(-16.032)	(-8.097)	(-8.414)	(-9.312)[b]

[a]See Table 5.1 for variable definitions.

[b]Figures in parentheses are average percent changes over years 1978-79 and 1982-1986.

Table 7.5. Percent changes in production and input demand under a 100 percent increase in set-aside requirements[a]

YEAR	WHEPD	RICPD	CORPD	OCGPD	SOYPD	HAYPD	COTPD	PNTPD	FXSPD
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	-0.079	0.235	0.274	-0.277	0.005	-0.094	0.050	-0.108	1.218
1979	-0.040	0.127	0.107	-0.119	0.001	-0.046	0.029	-0.052	0.334
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.003	-0.242	-0.007	0.109	-0.006	0.004	-0.498	-0.085	-0.250
1983	0.052	1.189	0.626	0.920	-0.007	-0.036	-1.015	-0.096	0.040
1984	0.128	-0.701	-0.010	0.238	-0.009	0.042	-0.900	-0.168	-0.603
1985	0.106	0.074	-0.007	0.099	-0.015	0.003	-1.016	-0.183	-0.368
1986	0.027	-1.049	0.044	-1.307	-0.000	-0.031	-1.239	-0.277	0.681
Avg	0.008	-0.014	0.040	0.038	-0.001	-0.006	-0.177	-0.037	0.040
Avg*[b]	0.028	-0.052	0.147	0.140	-0.004	-0.023	-0.656	-0.138	0.150

[a]See Table 5.1 for variable definitions.

[b]Average over years 1978-79 and 1982-86.

Table 7.5. (continued)

YEAR	SUGPD	TOBPD	VEGPD	FUNPD	LANUS	FERUS	OPCUS	LABUS
1961	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1962	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1963	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1964	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1965	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1966	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1972	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.418	-0.448	0.263	-0.135	-0.000	-0.041	-0.098	0.177
1979	0.197	-0.205	0.148	-0.071	0.000	-0.033	-0.043	0.090
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	-0.294	0.299	-0.079	0.074	-0.001	-0.061	0.043	-0.312
1983	-0.027	0.030	0.031	0.013	-0.006	-0.039	-0.003	0.100
1984	-0.720	0.885	-0.203	0.186	0.005	-0.158	0.119	-0.520
1985	-0.527	0.661	-0.126	0.140	-0.004	-0.134	0.090	-0.585
1986	-0.638	0.890	0.089	0.152	0.012	-0.289	0.121	-0.656
Avg	-0.061	0.081	.0.005	0.014	0.000	-0.029	0.009	-0.066
Avg*[b]	-0.227	0.302	0.018	0.051	0.001	-0.108	0.033	-0.244

(1988), set-asides are represented through a effective support price resulting erroneously in an unambiguous negative effect of set-asides on production.

As a result of an increase in set-asides, use of land and fertilizer inputs is down (Table 7.5). The effects for operating capital and labor varied, again, from year to year. It should be noted that these are aggregate input demands. No inferences could be made on crops specific input use from the model.

Concluding Remarks

This Chapter has illustrated how the estimated output supply and input demand equations with their policy structure can be used for policy analysis. In addition, the empirical model was used to validate selected important comparative statics results in Chapter III. Specifically, it was shown that increasing target prices (set-aside requirements) would result in an increase (decrease) in program participation rate. The estimated model used for policy simulations, however, does not contain consumer demand and input supply equations. Hence, the empirical policy results reported in this chapter are only partial since no simultaneous price determination mechanism was incorporated. In fact, the policy framework of the estimated model can be fully exploited if incorporated in a general equilibrium model.

CHAPTER VIII. SUMMARY

The present study was conducted with two overall objectives. The first was to develop a theoretical model of the producer decisions for participation in voluntary commodity programs and to structurally incorporate the government program variables in crop output supply and input demand system. The second objective was to estimate theoretically consistent crop supply and input demand system with a detailed policy structure for the U.S. crop sector.

A theoretical model incorporating agricultural producers decision on whether to comply with the volunteer commodity programs was developed. This theoretical model formed the basis for the empirical specifications of policy structure used for the econometric analysis. Unlike previous studies, policy variables were directly incorporated in a structural framework.

The properties of duality were exploited in constructing the empirical model. More specifically, a multi-output profit function technology in dual framework was used in the present study. A normalized quadratic profit function was used to derive product supply and variable input demand equations. Policy parameters were implemented directly in the output supply and input demand equations in a structural framework following the theoretical model.

Thirteen crop supply (wheat, rice, corn, other coarse grains, soybeans, hay, cotton, peanuts, flaxseed and sunflower, sugarcane and sugarbeet, tobacco, vegetables, and fruits and nuts) and four variable input demand (land, fertilizer, operating capital, and labor) equations were estimated simultaneously using full information maximum likelihood estimation and allowing for contemporaneous correlation of additive errors. Annual aggregate time series data for the U.S. agriculture were used in the estimation. The sample period extended from years 1950 through 1986. In estimation, homogeneity and symmetry of the restricted profit function were maintained. Estimates indicated that monotonicity of the profit function was not violated. Using Cholesky factorization, convexity of the restricted profit function was tested and rejected. To maintain theoretical consistency, convexity is nevertheless imposed. The parameter estimates implied plausible own price elasticities. In general, estimated cross price elasticities were small.

In addition, equations for commodity program participation rates for wheat, rice, corn, other coarse grains, and cotton are estimated. The explanatory variables and functional form for these participation equations are chosen in accordance with the theoretical model. The estimated parameters are consistent with the theory and implied plausible elasticities.

The estimated model performed well in a historical simulation. The estimated model was then used to conduct policy analyses. Results indicated that an increase in target prices (set-aside requirements) results in an increase (decrease) in program participation rate. Effects of an increase in target price on production and input use varied from crop to crop and from year to year. As a result of a simultaneous 10 percent increase in all target prices, productions for wheat, other coarse grains, and cotton increased. Production for other coarse grains increased the most; by an average of 1.4 percent per year. Corn production decreased by an average of 0.2 percent due to a 10 percent increase in all target prices. Higher target prices resulted in more intensive use of all inputs.

The study took a bold first step toward incorporating a policy structure in a theoretically sound framework for crop supply analysis. The incorporation of policy parameters in a structural way, as opposed to reduced form representations, combined with a rigorous microeconomic theory sets the present study apart and represents a contribution to the areas of applied production analysis and quantitative policy evaluation. The empirical results are promising and indicated that microeconomic theory can be fruitfully and meaningfully combined with a structural implementation of policy parameters in the U.S. agricultural sector.

Though the results from the present study are satisfactory in several aspects, some improvements can be made in the model. First, the treatment of loan rates and their impact on the expectations of non-participants could be made more explicit. When program participation rate is high, the loan rate effectively forms a lower bound to the market price. Hence, non-participants are also better off, since their market price is now at least as high as loan rate. The present study does not capture these effects explicitly. A rational expectations hypothesis is necessary to fully capture these market feedback mechanisms between participants, non-participants, and anticipated market price or output level. The policy structure developed in the present study can be elaborated to explicitly treat loan rates and base acres. To incorporate base acres, a dynamic specification - another aspect omitted in the present study - will be required. A dynamic specification is also desirable to model the production of certain crops such as fruits and nuts due to their perennial nature.

Improvements can also be made to the estimated participation rate equations also. Specifically, it would be desirable to incorporate cross price effects in the participation rate equations. Also, it might prove to be beneficial to estimate the participation rate equations simultaneously with the rest of the system. Finally, the rich policy structure in the estimated supply and input demand equations, can be fully exploited for policy analysis, when incorporated in a general equilibrium model for the U.S. economy.

REFERENCES

Abkin, Michael H. 1985. "The intermediate United States Food and Agriculture Model of the IIASA/FAP Basic Link System: Summary Documentation and User's Guide." WP-85-30. International Institute for Applied Systems Analysis, Laxemberg, Austria.

Adelman, Irma and Alexander Sarris. 1982. "Incorporating Uncertainty into Planning of Industrialization Strategies for Developing Countries." World Bank Staff Working Paper No. 503.

Adelman, Irma and Sherman Robinson. 1985. "Macroeconomic Adjustment and Income Distribution: Alternative Models in Two Economies." Working Paper No. 385. Department of Agricultural and Resource Economics, University of California, Berkeley.

Adelman, Irma and Sherman Robinson. 1986. "U.S. Agriculture in a General Equilibrium Framework: Analysis with a Social Accounting Matrix." American Journal of Agricultural Economics 68: 1190-1207.

Adelman, Irma and J. Edward Taylor, eds. 1986. The Design of Alternative Development Strategies. Rohtak, India: Jan Tinbergen Institute of Development Planning.

Adelman, Irma, Alexander H. Sarris, and David M. Wells. 1986. "Modeling Uncertainty with Computable General Equilibrium Models." University of California, Berkeley, Department of Agricultural and Resource Economics. Mimeo.

Ahluwalia, Montek S., and Frank J. Lysy. 1979. "Welfare Effects of Demand Management Policies: Impact Multipliers Under Alternative Model Structures." Journal of Policy Modeling 1: 317-42.

Andereson, Kym, and Yujiro Hayami. 1986. The Political Economy of Agricultural Protection. Boston: Allen and Unwin Publishers.

Anderson, J. E. 1985. "The Relative Inefficiency of Quotas: The Cheese Case." American Economic Review 75: 178-190.

Anderson, J. R., J. L. Dillon, and B. Hardarker. 1977. Agricultural Decision Analysis. Ames: Iowa State University Press.

Antle, John M. 1983. "Incorporating Risk in Production Analysis." American Journal of Agricultural Economics 65: 1099-1106.

Antle, John M. 1984. "The Structure of U.S. Agricultural Technology, 1910-78." American Journal of Agricultural Economics 66: 414-21.

Antle, John M. 1987. "Econometric Estimation of Producers' Risk Attitudes." American Journal of Agricultural Economics 68: 509-22.

Antle, John M., and Stephen A. Hatchett. 1986. "Dynamic Input Decisions in Econometric Production Models." American Journal of Agricultural Economics 68: 939-49.

Appelbaum, Elie. 1978. "Testing Neoclassical Production Theory." Journal of Econometrics 7: 87-102.

Aradhyula, Satheesh. 1988. "On the Theory of the Competitive Firm under Price Uncertainty: The Case of Multiproduct Firm." Paper presented at the Annual Meetings of the Midwest Economic Association, Chicago, Illinois, April 21-23.

Aradhyula, Satheesh, and Matthew T. Holt. 1989. "Risk Behavior and Rational Expectations in the U.S. Broiler Industry." American Journal of Agricultural Economics Forthcoming.

Aradhyula, Satheesh, K. Eswaramoorthy, and Klaus Frohberg. 1988. "An Application of the Computable General Equilibrium Model to Analyze U.S. Agriculture." Working Paper 88-WP26. Center for Agricultural and Rural Development, Iowa State University, Ames.

Armington, Paul. 1969. "A Theory of Demand for Products Distinguished by Place of Production." International Monetary Fund Staff Papers 16: 159-178.

Arrow, K. J., and G. Debreu. 1954. "Existence of an Equilibrium for a Competitive Economy." Econometrica 22: 265-290.

Artus, P., and W. Guvenen, eds. 1986. International Macroeconomic Modeling for Policy Decisions. Dordrecht, Netherlands: Martinus Nijhoff Publisher.

Arzac, Enrique R., and M. Wilkinson. 1979. "A Quarterly Model of United States Livestock and Feed Grain Markets and some of its Policy Implications." American Journal of Agricultural Economics 61: 297-308.

Askari, H., and J. T. Cummings. 1977. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey." International Economic Review 18: 257-292.

Baffes, J., and U. Vasavada. 1989. "On the Choice of Functional Forms in Agricultural Production Analysis." Applied Economics Forthcoming.

Ball, Eldon V. 1986. "Output, Input, and Productivity Measurement in U. S. Agriculture, 1948-79." American Journal of Agricultural Economics 67: 475-486.

Ball, Eldon V. 1988. "Modeling Supply Response in a Multiproduct Framework." American Journal of Agricultural Economics 70: 813-825.

Ball, Eldon V. 1989. "Estimating Supply Response of Multiproduct Farms." Technical Bulletin No. 1750. Economic Research Service, United States Department of Agriculture.

Ball, Eldon V., and Robert G. Chambers. 1982. "An Economic Analysis of Technology in the Meat Products Industry." American Journal of Agricultural Economics 64: 699-709.

Ball, R. J. 1978. The International Linkage of National Economic Model. Amsterdam: North Holland Publishing Company.

Ballard, Charles L., John B. Shoven, and John Whalley. 1982. "The Welfare Costs of Distortions in the U.S. Tax System. A General Equilibrium Approach." Working Paper No. 1043. National Bureau of Economic Research, Cambridge, Massachusetts.

Ballard, Charles L., T. Fullerton, J. B. Shoven, and J. Whalley. 1985. A General Equilibrium Model for Tax Policy Evaluation. Chicago: University of Chicago Press.

Barclay, Thomas N. 1986. "Macroeconomic Impacts on United States Agriculture: A Simulation Analysis." Unpublished Ph.D. dissertation. Oklahoma State University, Stillwater.

Barnett, William A. 1983a. "New Indices of Money Supply and the Flexible Laurent Demand System." Journal of Business and Economic Statictics 1: 7-23.

Barnett, William A. 1983b. "Definitions of 'Second Order Approximation' and of 'Flexible Functional Form'." Economics Letters 12: 31-35.

Barnett, William A. 1985. "The Miniflex-Laurent Translog Flexible Functional Form." Journal of Econometrics 30: 33-44.

Baxter, N. D., and J. L. Cragg. 1970. "Corporate Choice among Long-Term Financing Instruments." Review of Economics and Statistics 52: 225-235.

Beattie, Bruce R., and C. Robert Taylor. 1985. The Economics of Production New York: John Wiley and Sons.

Bergman, L. 1982. "A System of Computable General Equilibrium Models for a Small Open Economy." Mathematical Modeling 3: 421-435.

Berndt, E. R., and L. R. Christensen. 1973. "The Translog Function and the Substitution of Equipment, Structures, and Labor in U.S. Manufacturing, 1929-68." Journal of Econometrics 2: 81-113.

Blackorby, C., and W. Schworm. 1982. "Aggregate Investment and Consistent Intertemporal Technologies." Review of Economic Studies 49: 595-614.

Blackorby, C., and W. Schworm. 1988. "The Existence of Input and Output Aggregates in Aggregate Production Function." Econometrica 56: 613-643.

Blackorby, C., D. Primont, and R. Russel. 1977. "On Testing Separability Restrictions with Flexible Functional Forms." Journal of Econometrics 5: 195-209.

Blackorby, C., D. Primont, and R. Russel. 1978. Duality, Separability and Functional Structure: Theory and Economic Applications. New York: North-Holland Publishing Company.

Blair, Roger, D., and Rafael Lusky. 1977. "A Note on Random Demand and Duality Under Competition." International Economic Review 18: 235-240.

Blitzer, Charles R., Peter B. Clark, and Lance Taylor, eds. 1975. Economy-Wide Models and Development Planning. Oxford: Oxford University Press.

Boisvert, R. N. 1986. "A General Measure of Output-Variable Input Demand Elasticities." American Journal of Agricultural Economics 68: 745-746.

Borges, A. M. 1987. "Applied General Equilibrium Models and Agricultural Policy Evaluation." INSEAD, Fontainebleau.

Brandow, G. E. 1977. "Policy for Commercial Agricultue, 1945-71." In Survey of Agricultural Economics Literature. Edited by Lee Martin. Minneapolis: University of Minnesota Press.

Branson, W. H. 1979. Macroeconomic Theory and Policy. New York: Harper and Row Publishers.

Bullock, J. Bruce. 1984. "Future Directions for Agricultural Policy." American Journal of Agricultural Economics 66: 234-239.

Burt, Oscar R., and V. E. Worthington. 1988. "Wheat Acreage Supply Response in the United States." Western Journal of Agricultural Economics 13: 100-111.

Bunch, D. S. 1988. "A Comparision of Algorithms for Maximum Likelihood Estimation of Choice Models." Journal of Econometrics 38: 145-168.

Capalbo, Susan M., and Michael G. S. Denny. 1986. "Testing Long-Run Productivity Models for the Canadian and U. S. Agricultural Sectors." American Journal of Agricultural Economics 68: 615-625.

Caves, Douglas W., and Laurits Christensen. 1980. "Global Properties of Flexible Functional Forms." American Economic Review 70: 422-432.

Chalfant, J. A., and A. R. Gallant. 1985. "Estimating Substitution Elasticity with Fourier Form - Some Monte Carlo Results." Journal of Econometrics 28: 205-222.

Chalfant, J. A., R. S. Gray, and K. J. White. 1989. "Evaluating Prior Beliefs in a Demand System: The Case of Meat Demand in Canada." Working Paper No. 483. Department of Agricultural Economics, University of California, Berkeley.

Chambers, Robert G. 1988. Applied Production Analysis: A Dual Approach. New York: Cambridge University Press.

Chambers, Robert G., and William E. Foster. 1983. "Participation in the Farmer-Owened Reserve: A Discrete Choice Model." American Journal of Agricultural Economics 65: 120-124.

Chambers, Robert G., and Richard E. Just. 1982. "Effects of Exchange Rates on U.S. Agriculture: A Dynamic Analysis." American Journal of Agricultural Economics 63: 294-59.

Chambers, Robert G., and Richard E. Just. 1988. "Estimating Multioutput Technologies." Working Paper No. 88-19. Department of Agricultural and Resource Economics, University of Maryland, College Park.

Chambers, Robert G., and R. Lopez. 1984. "A General Dynamic, Supply-Response Model." Northeast Journal of Agricultural and Resource Economics 13: 142-54.

Chang, Ching-Cheng, and Richard Shumway. 1988. "Sensitivity of Supply Elasticities to Model Specification." Paper Presented at the annual meeting of the American Agricultural Economics Association, Knoxville, Tennessee, July 31 - August 3.

Chattin, Barbara L. 1987. "Measures of Government Intervention the U.S. Wheat, Corn, Sugar, and Dairy Markets." Paper presented at the annual meeting of the American Agricultural Economics Association, East Lansing, Michigan, August 2-5.

Chavas, Jean-Paul, and Richard M. Klemme. 1986. "Aggregate Milk Supply Response and Investment Behavior on U. S. Dairy Farms." American Journal of Agricultural Economics 68: 55-66.

Choi, E. K., and S. R. Johnson. 1987. "Demand Uncertainty and Price Stabilization." Working Paper 87-WP23. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

Christensen, Laurits R., Dale W. Jorgenson, and Lawrence J. Lau. 1973. "Transcendental Logarithmic Production Frontiers." The Review of Economics and Statistics 55: 28-45.

Chung, Jae-Wan. 1987. "On the Estimation of factor substitution in the translog model." The Review of Economics and Statistics 69: 392-398.

Clarete, R., and J. Roumasset. 1986. "Modeling Agricultural Development Policy: A General Equilibrium Approach." Discussion paper 86-7. School of Economics, University of the Philippines, Manila.

Clements, Kenneth W. 1977. "The Trade Balances in Monetary General Equilibrium." Unpublished Ph.D. dissertation. University of Chicago, Chicago.

Clements, Kenneth W. 1980. "A General Equilibrium Econometric Model of an Open Economy." International Economic Review 21 :469-88.

Clements, Kenneth W., and H. Y. Izan. 1981. "A Note on Estimating Divisia Index Numbers." International Economic Review 22: 745-747.

Cochrane, W. W., and M. E. Ryan. 1976. American Farm Policy, 1948-1973. Minneapolis: University of Minnesota Press.

Colman, David. 1983. "A Review of the Arts of Supply Response Analysis." Review of Marketing and Agricultural Economics 51: 201-230.

Daal, J. V., and A. H. Merkies. 1984. Aggregation in Economic Research. Boston: Reidel Publishing Company.

Deardorff, A., and R. M. Stern. 1981. "A Disaggregated Model of World Production and Trade: An Estimate of the Impacts of the Tokyo Round." Journal of Policy Modeling 3: 127-152.

Deaton, Angus and John Muellbauer. 1980. Economics and Consumer Behavior. New York: Cambridge University Press.

Decaluwe, Bernard, and Andre Martens. 1988. "CGE Modeling and Developing Economies: A Concise Empirical Survey of 73 Applications to 26 Countries." Journal of Policy Modeling 10: 529-568.

de Gorter, Harry. 1987. "Assessing the Consequences of U.S. Farm Policy on World Markets." Paper presented at the GATT Agriculture Policy Modeling Workshop, Center for the Study of International Economic Relations, University of Western Ontario, London.

de Gorter, Harry, and Brian W. Paddock. 1985. "The Impact of U.S. Price Support and Acreage Production Measures on Crop Output." International Trade Policy Division, Agriculture Canada. Mimeo.

de Janvry, A., and E. Sadoulet. 1986. "Agricultural Growth in Developing Countries and Agricultural Imports: Econometric and General Equilibrium Analysis." Working Paper No. 424. Department of Agricultural and Resource Economics, University of California, Berkeley.

de Melo, Jaime. 1988. "SAM-Based Models: An Introduction." Journal of Policy Modeling 10: 321-327.

Dervis, Kemal, Jaime de Melo, and Sherman Robinson. 1982. General Equilibrium Models for Development Policy. New York: Cambridge University Press.

Devarajan, Shantayanan, Jeffrey D. Lewis, and Sherman Robinson. 1986. "A Bibliography of Computable General Equilibrium (CGE) Models Applied to Developing Countries." Working Paper No. 400. Giannini Foundation of Agricultural Economics, University of California, Berkeley.

Dewatripont, Mathias, and Gilles Michel. 1987. "On Closure Rules, Homogeneity, and Dynamics in Applied General Equilibrium Models." Journal of Development Economics 26: 65-76.

Dewatripont, Mathias, and Sherman Robinson. 1985. "The Impact of Price Rigidities: A Computable General Equilibrium Analysis." Working Paper No. 375. Giannini Foundation of Agricultural Economics, University of California, Berkeley.

Dhrymes, P. J. 1978. Introductory Econometrics. New York: Springer-Verlag.

Diewert, W. E. 1971. "An Application of the Shephard Duality Theorm: A Generalized Leontief Production Function." Journal of Political Economy 79: 481-507.

Diewert, W. E. 1973. "Functional Forms for Profit and Transformation Functions." Journal of Economic Theory 6: 284-316.

Diewert, W. E. 1974. "Application of Duality Theory." In Frontiers of Quantitative Economics. Edited by M. Intriligator and D. Kendrick. Amsterdam: North-Holland.

Diewert, W. E. 1976. "Exact and Superlative Index Numbers." Journal of Econometrics 4: 115-145.

Diewert, W. E. 1978. "Superlative Index Numbers and Consistency in Aggregation." Econometrica 46: 883-900.

Diewert, W. E., and T. J. Wales. 1987. "Flexible Functional Forms and Global Curvature Conditions." Econometrica 55: 43-68.

Diewert, W. E., and T. J. Wales. 1988. "A Normalized Quadratic Semi-flexible Functional Form." Journal of Econometrics 37: 327-342.

Dixon, P. B., B. R. Parmenter, and R. J. Rimmer. 1984. "Extending the ORANI model of the Australian Economy: Adding Foreign Investment to a miniature version." In H. E. Scarf and J. B. Shoven eds. Applied general Equilibrium Analysis. Cambridge: Cambridge University Press.

Driscoll, Paul J., and Richard N. Boisvert. 1988. "Empirical Implications of Reconciling the Behavioral Assumptions in Dual Models of Productions." Working Paper No. 88-9. Department of Agricultural Economics, Cornell University, Ithaca.

Drud, A., W. Grais, and G. Pyatt. 1986. "Macroeconomic Modeling Based on Social Accounting Principles." Journal of Policy Modeling 8: 111-45.

Duncan, G. M. 1980. "Formulation and Statistical Analysis of the Mixed, Continuous/Discrete Dependent Variable Model in Classic Production Theory." Econometrica 48: 839-852.

Eckstein, Zvi. 1985. "The Dynamics of Agricultural Supply: A Reconsideration." American Journal of Agricultural Economics 67: 204-214.

Eeckhoudt, L., and P. Hansen. 1980. "Minimum and Maximum Prices, Uncertainty, and the Theory of the Competitive Firm." American Economic Review 70: 1064-1068.

Epstein, Larry G. 1981. "Duality Theory and Functional Forms for Dynamic Factor Demands." Review of Economic Studies 48: 81-95.

Epstein, Larry G. 1983. "Generalized Duality and Integrability." Econometrica 49: 655-678.

Federal Reserve Bank of Kansas City. 1986. Competing in the World Market Place: The Challenge for American Agriculture. Kansas City: Federal Reserve Bank of Kansas City.

Feldstein, Martin, ed. 1983. Behavioral Simulation Methods in Tax Policy Analysis. Chicago: University of Chicago Press.

Fischer G., K. Frohberg, M. Keyzer, and K. Parikh. 1988. "Linked national models: A tool for international food policy analysis." Dordrecht, The Netherlands: Kluwer Academic Publishers.

Food and Agricultural Policy Research Institute. 1987a. "Comparative Analysis of Selected Policy Options for U.S. Agriculture." Staff Report 1-87. Center for Agricultural and Rural Development, Iowa State University, Ames.

Food and Agricultural Policy Research Institute. 1987b. "Managing the Food Security Act of 1985: The Current Strategy and Two Alternatives." Staff Report 3-87. Center for Agricultural and Rural Development, Iowa State University, Ames.

Food and Agricultural Policy Research Institute. 1988. "Policy Scenarios with FAPRI Commodity Models" Working Paper No. WP88-41. Center for Agricultural and Rural Development, Iowa State University, Ames.

Fomby, Thomas B., R. Carter Hill, and Stanley R. Johnson. 1984. Advanced Econometric Methods. New York: Springer-Verlag.

Fox, Karl, A. 1951. "The Measurement of Price Support Costs." Journal of Farm Economics 33: 470-484.

Fox, Karl, A. 1965. "A Submodel of the Agricultural Sector." In The Brookings Quarterly Econometric Model of the United States. Edited by James S. Duesenbarry. Chicago: Rand McNally and Company.

Fox, Karl, A., and Harry C. Norcross. 1952. "Some Relationships between Agriculture and the General Economy." Agricultural Economics Research 4: 13-21.

Freebairn, J. W., and G. C. Rausser. 1975. "Effects of Changes in the Level of U.S. Beef Imports." American Journal of Agricultural Economics 57: 676-688.

Frenkel, J. A., and H. G. Johnson, eds. 1978. "The Economics of Exchange Rates: Selected Studies." Reading, Mass.: Addison-Wesley.

Frohberg, Klaus, Satheesh V. Aradhyula, D. Maxwell, and S. R. Johnson. 1988. "CARD/BLS Model Results" Report presented at the Policy Modeling Symposium, Annual Meetings of the American Agricultural Economics Association, Knoxville.

Fuss, M. 1977. "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with many Inputs." Journal of Econometrics 5: 89-116.

Fuss, M., and M. McFadden, eds. 1978. Production Economics: A Dual Approach to Theory and Applications. Amsterdam: North-Holland Publishing Company.

Gadson, K. E., J. M. Price, and L. E. Salathe. 1982. "The Food and Agricultural Policy Simulator (FAPSIM): Structural Equations and Variable Definitions." Staff Report AGES 820506. Economic Research Service, United States Department of Agriculture.

Gallant, Ronald A. 1981. "On the Bias in Flexible Functional Forms and an Essentially Unbiased Form: The Fourier Flexible Form." Journal of Econometrics 15: 211-245

Gallant, Ronald A. 1982. "Unbiased Determination of Production Technologies." Journal of Econometrics 20: 285-323.

Gallant, Ronald A. 1984. "The Fourier Flexible Form." American Journal of Agricultural Economics 66: 204-208.

Gallant, Ronald A., and Gene H. Gloub. 1984. "Imposing Curvature Restrictions on Flexible Functional Forms." Journal of Econometrics 26: 295-321.

Gardiner, Walter, and Praveen Dixit. 1987. "The Price Elasticity of Export Demand for U.S. Agricultural Products; Methods and Estimates." Paper presented at the 1987 Annual Meetings of Southern Agricultural Economics Association, February 2-4, Nashville, Tennessee.

Gardner, Bruce L. 1981. The Governing of Agriculture. Lawrence: The Regents Press of Kansas.

Gardner, B. L. 1985. "Economic Consequences of U.S. Agricultural Policies." Washington, D. C.: World Bank.

Gardner, B. L. 1987. "Causes of U.S. Farm Commodity Programs." Journal of Political Economy 95: 290-310.

Gardner, B. L., and J. P. Chavas. 1979. "Market Equilibrium with Random Production." Paper Presented at the Annual Meetings of the American Agricultural Economics Association, Pullman.

Glaser, Lewrene K. 1986. "Provisions of the Food Security Act of 1985." Agricultural Information Bulletin Number 498. United States Department of Economics, Economic Research Service, Washington, D. C.

Goodwin, Thomas H., and Steven M. Sheffrin. 1982. "Testing the Rational Expectations Hypothesis in an Agricultural Market." Review of Economics and Statistics 64: 558-567.

Gorman, W. M. 1968. "Measuring the Quantities of Fixed Factors." In Value, Capital and Growth: Papers in Honour of Sir John Hicks. Edited by H. N. Wolfe. Chicago: Aldine Press.

Green, H. A. J. 1964. Aggregation in Economic Analysis. Princeton: Princeton University Press.

Griffin, R. C., J. Montgomery and E. Rister. 1987. "Selecting Functional Form in Production Analysis." Western Journal of Agriclutural Economics 12: 216-27.

Groenewegen, John, and Kenneth Clayton. 1982. "Agricultural Price Supports and Cost of Production." American Journal of Agricultural Economics 64: 271-275.

Groenewegen, John, and Kenneth Clayton. 1983. "Agricultural Price Supports and Cost of Production: Reply." American Journal of Agricultural Economics 65: 626-628.

Grube, Arthur, H. 1986. "Participation in Farm Commodity Programs: A Stochastic Dominance Analysis. Comment." American Journal of Agricultural Economics 68: 185-188.

Hall, D. C., and G. M. Duncan. 1984. "Econometric Evaluation of New Technology with an Application to Integrated Pest Managment." American Journal of Agricultural Economics 66: 624-633.

Hallam, Arne, Richard Just, and Rulon Pope. 1982. "Positive Economic Analysis and Risk Considerations in Agricultural Production." In New Directions in Econometric Modeling and Forecasting in U.S. Agriculture. Edited by G. Rausser. Amsterdam: North-Holland.

Hamilton, C. 1986. "A General Equilibrium Model of Structural Change and Economic Growth, with Application to South Korea." Journal of Development Economics 23: 67-88.

Hanenmann, W., and Y. Tsur. 1982. "Econometric Models of Discrete/ Continuous Supply Decisions Under Uncertainty." Working Paper No. 195. Giannini Foundation of Agricultural Economics, University of California, Berkeley.

Hanoch, Giora. 1975. "Production and Demand Models with Direct Indirect Implicit Additivity." Econometrica 43: 395-419.

Hanson, Kenneth A., and Sherman Robinson. 1989. "Data, Linkages, and Models: U.S. National Income and Product Accounts in the Framework of a Social Accounting Matrix." Staff Report No. 89-5. Agriculture and Rural Economy Division, Economic Research Service, U.S. Department of Agriculture, Washington, D. C.

Hanthorn, M., and J. W. Glauber. 1987. "An Assessment of Marketing Loan Program Options." Agricultural Economics Report No. 581. Economic Research Service, U. S. Department of Agriculture, Washington, D. C.

Harvey, A. C. 1981. The Econometric Analysis of Time Series. Oxford: Phillip Alan.

Hasenkamp, G. 1976a. Specification and Estimation of Multi-output Production Functions. New York: Springer-Verlag.

Hasenkamp, G. 1976b. "A Study of Multiple-Output Production Functions: Klein's Railroad Study Revised." Journal of Econometrics 4: 253-262.

Heathfield, David F., and Sorem Wibe. 1987. An Introduction to Cost and Production Functions. Basingstoke: Macmillan Publishing Company.

Heien, D. 1977. "The Cost of the U.S. Dairy Price Support Program." Review of Economics and Statistics 59: 1-8.

Helms, J. L. 1985. "Errors in the Numerical Assessment of the Benefits of Price Stabilization." American Journal of Agricultural Economics 67: 93-100.

Henderson, J. M., and R. E. Quandt. 1980. Microeconomic Theory. New York: McGraw-Hill Book Company.

Hertel, Thomas W. 1984. "Application of Duality and Flexible Functional Forms: The Case of the Multiproduct Firm." Indiana Agricultural Experiment Station, Research Bulletin 980.

Hertel, Thomas W. 1985. "Partial vs. General Equilibrium Analysis and Choice of Functional Form: Implications for Policy Modeling." Journal of Policy Modeling 7: 281-303.

Hertel, Thomas W. 1986. "Doable General Equilibrium Models: Discussion." Journal of Agricultural Economics 68: 1222-1224.

Hertel, Thomas W. 1988. "Economywide Analysis of U.S. Agriculture: What Have we Learned and How can we Teach it?" Staff Peper No. 88-8. Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.

Hertel, Thomas W., and Lance McKinze. 1986. "Pseudo Data as a Teaching Tool: Application to the Translog, Multiproduct Profit Function." Western Journal of Agricultural Economics 11: 19-30.

Hertel, Thomas W., and Marinos E. Tsigas. 1987. "General Equilibrium Analysis of Supply Control in U.S. Agriculture." Staff Paper 87-25. Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.

Hill, B. 1982. "Concepts and Measurements of the Incomes, Wealth, and Economic Well-being of Farmers." Journal of Agricultural Economics 33: 311-24.

Holt, M. T. 1987. "Uncertainty and the Microfoundations of Supply Response: Some Theoretical Considerations and An Empirical Application in the U.S. Corn Market." Unpublished Ph.D. dissertation. University of Missouri, Columbia.

Houck, J. P. 1986. Elements of Agricultural Trade Policies. Macmillan Publishing Company: New York.

Houck, J. P., and M. E. Ryan. 1972. "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs." American Journal of Agricultural Economics 54: 184-91.

Howard, Wayne H., and Richard Shumway. 1988. "Dynamic Adjustment in the U. S. Dairy Industry." American Journal of Agricultural Economics 70: 837-847.

Hughes, Dean W., and John B. Penson. 1980. "Description and Use of a Macroeconomic Model of the U.S. Economy Which Emphasizes Agriculture." Texas A&M University, Department of Agricultural Economics, Departmental Technical Report 20, DTR 80-5.

Johansen, L. 1974. A Multi-sectoral Study of Economic Growth. Amsterdam: North-Holland, Second Edition.

Johnson, James D., and Sara D. Short. 1983. "Commodity programs: Who has received the benefits?" American Jouranl of Agricultural Economics 65: 912-921.

Johnson, Stanley R. 1981. "Alternative Designs for Policy Models of the Agricultural Sector." In Modeling Agriculture for Policy Analysis in the 1980s. Kansas City: Federal Reserve Bank of Kansas City.

Johnson, Stanley R. 1986. "Doable General Equilibrium Models: Discussion." American Jouranl of Agricultural Economics 68: 1217-1218.

Johnson, Stanley R., William H. Meyers, Patrick Westhoff, and Abner Womack. 1988. "Agricultural Market Outlook and Sensitivity to Macroeconomic Productivity, and Policy Changes." Working Paper No. 88-WP36. Center for Agricultural and Rural Development, Iowa State University, Ames.

Judge, George G., C. R. Hill, W. E. Griffiths, H. Lutkepohl, and T. C. Lee. 1988. Introduction to the Theory and Practice of Econometrics. Second Edition. New York: John Wiley and Sons.

Just, Richard E. 1974. "An Investigation of the Importance of Risk in Farmers' Decisions." American Journal of Agricultural Economics 56: 659-66.

Just, Richard, E., and David Zilberman. 1983. "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." Oxford Economic Papers 35: 307-328.

Just, Richard, E., David Zilberman, and Eithan Hochman. 1983. "Estimation of Multicrop Production Functions." American Journal of Agricultural Economics 65: 770-780.

Karp, Larry and Richard Shumway. 1984. "Issues and Methods in Estimating Adjustment Costs." Northeast Journal of Agricultural and Resource Economics 13: 155-177.

Kehoe, Timothy and Serra-Puche. 1983. "A Computable General Equilibrium Model with Endogenous Unemployment." Journal of Public Economics 22: 1-26.

Kelley, A. C., W. C. Sanderson, and J. G. Williamson, eds. 1983. Modelling Growing Economies in Equilibrium and Disequilibrium. Durham, N.C.: Duke University Press.

Kim, Youn, H. "Economies of Scale in Multi-Product Firms." Economica 54: 185-206.

King, Benjamin B. 1981. "What is a SAM? A Layman's Guide to Social Accounting Matrices." World Bank Staff Working Paper No. 463.

Kmenta, Jan. 1986. Elements of Econometrics. New York: Macmillan Publishing Company.

Koester, U. 1985. "Agricultural Market Intervention and International Trade." European Review of Agricultural Economics 12: 87-103.

Kohli, Ulrich, R. 1981. "Nonjointness and factor intensity in U. S. Production." International Economic Review 22: 3-18.

Kokoski, Mary F., and V. Kerry Smith. 1985. "General Equilibrium Welfare Measurements: A Cautionary Note." Working Paper No. 85-W-21. Vanderbilt University, Nashville, Tennessee.

Kokoski, Mary F., and Kerry Smith. 1987. "A General Equilibrium Analysis of Partial-Equilibrium Welfare Measures: The Case of Climate Change." American Economic Review 77: 331-341.

Kramer, Randall, A., and Rulon D. Pope. 1981. "Participation in Farm Commodity Programs: A Stochatic Dominance Analysis." American Journal of Agricultural Economics 63: 119-128.

Krelle, W. 1983. "The Aggregate Production Function and the Representative Firm." In Global Econometrics. Essays in Honor of Lawrence R. Klein. Edited by Gerard Adams and Bert Hickman. London: The MIT Press.

Kulatilaka, N. 1985. "Are Observed Technologies at Long-Run Equilibrium? Tests on the Validity of Static Equilibrium Models." Journal of Econometrics 25: 253-268.

Laitinen, Kenneth. 1980. A Theory of the Multiproduct Firm. New York: North-Holland Publishing Company.

Laitinen, Kenneth, and H. Theil. 1978. "Supply and Demand of the Multiproduct Firm." European Economic Review 11: 107-154.

Lau, L. J. 1976. "A Characterization of the Normalized Restricted Profit Function." Journal of Economic Theory 12: 131-163.

Lau, L. J. 1978. "Applications of Profit Functions. In Production Economics: A Dual Approach to Theory and Applications. Eds. M. Fuss and D. McFadden, Vol. 1, Chapter I.3. Amsterdam: North-Holland Publishing Co.

Lau, L., and P. Yotopolous. 1972. "Profit, Supply, and Factor Demand Functions." American Journal of Agricultural Economics 54: 11-18.

Le Blanc, M. 1982. "Estimating Input Cost Shares for Agriculture Using a Multinomial Logit Framework." Agricultural Economic Research 34: 23-31."

Le Blanc, M., and J. Hrubovcak. 1986. "Dynamic Input Demand: An Application to Agriculture." Applied Economics 18: 807-818.

Lee, D. R., and P. G. Helmberger. 1982. "Structural Change in Acreage Supply Response Response: An Economtric Analysis of U.S. Feed Grain Programs, 1948-1980." Agricultural Economics Research Report No. 82-47. Department of Agricultural Economics, Cornell University, Ithaca.

Lee, D. R., and P. G. Helmberger. 1985. "Estimating Supply Response in the Presence of Farm Programs." American Journal of Agricultural Economics 67: 193-203.

Lee, Hyunok, and Robert G. Chambers. 1986. "Expenditure Constraints and Profit Maximization in U. S. Agriculture." American Journal of Agricultural Economics 68: 857-865.

Leong, Stephen. 1987. "Sectoral Analysis Using a Simple General Equilibrium Model." Paper presented at the Annual Meetings of Southern Agricultural Economics Association, Nashville, Tennessee, February 2-4.

Leu, Gwo-Jiun, M., Andrew Schmitz, and Ronald D. Knutson. 1987. "Gains and Losses of Sugar Program Policy Options." American Journal of Agricultural Economics 69: 591-602.

Lin, William, James Johnson, and Linda Calvin. 1981. "Farm Commodity Programs: Who participates and who benefits?" U. S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 474.

Linnemann, H., J. de Hoogh, M. A. Keyzer, and H. D. J. Van Heemst. 1979. MOIRA: A Model of International Relations in Agriculture. Amsterdam: North-Holland Publishing Company.

Lopez, R. E. 1980. "The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture." American Journal of Agricultural Economics 62: 38-45.

Lopez, Ramon E. 1982. "Application of Duality Theory to Agriculture." Western Journal of Agricultural Economics 7: 353-365.

Lopez, Ramon E. 1984. "Estimating Substitution and Expansion Effects Using a Profit Function Framework." American Journal of Agricultural Economics 66: 358-67.

Lopez, Ramon E. 1985. "Structural Implications of a Class of Flexible Functional Forms for Profit Functions." International Economic Review 26: 595-601.

Lucas, Robert E. 1981. "Econometric Policy Evaluation: A Critique." In Studies in Business Cycle Theory. Edited by Robert E. Lucas. Cambridge: The MIT Press. Pages 104-130.

Lutton, Thomas J. 1982. "Input Demand Formulations and Duality Theory." Agricultural Economic Research 34: 15-22.

Maddala, G. S. 1983. Limited-Dependent and Qualitative Variables in Econometrics. New York: Cambridge University Press.

Maddala, G. S. 1988. Introduction to Econometrics. New York: Macmillion Publishing Company.

Mahmud, S. F., A. L. Robb., and W. M. Scarth. 1987. "On Estimating Dynamic Factor Demands." Journal of Applied Econometrics 2: 69-76.

Manne, A. S., ed. 1985. Economic Equilibrium: Model Formulation and Solution. Mathematical Programming Study No. 23. Amsterdam: North-Holland Publishing Company.

Mansur, A., and J. Whalley. 1984. "Numerical Specification of Applied General Equilibrium Models: Estimation, Calibration, and Data." In Applied General Equilibrium Analysis. Eds. H. Scarf and J. Shoven. New York: Cambridge University Press.

McCalla, Alex F., and Timothy Josling. 1985. Agricultural Policies and World Markets. New York: Macmillan Publishing Company.

McCarthy, F. D., and L. Taylor. 1980. "Macro Food Policy Planning: A General Equilibrium Model for Pakistan." Review of Economics and Statistics 62: 107-121.

McKay, Lloyd, D. Lawrence, and Chris Vlastuim. 1983. "Profit, Output Supply, and Input Demand Functions for Multiproduct Firms: The Case of Australian Agriculture." International Economic Review 24: 323-339.

McKenzie, George W. 1983. Measuring Economic Welfare: New Methods. New York: Cambridge University Press.

McLaren, K. R., and R. J. Cooper. 1980. "Intertemporal Duality: Application to the Theory of the Firm." Econometrica 48: 1755-1762.

Meilke, Karl D., and Garry D. Griffith. 1983. "Incorporating Policy Variables in a Model of the World Soybean/Rapeseed Market." American Journal of Agricultural Economics 65: 65-73.

Melfi, C. A., and A. J. Rogers. 1988. "A Test for the Existence of Allocative Inefficiency in Firms." Journal of Applied Econometrics 3: 69-80.

Meyers, William H., Michael D. Helmar, and S. Devadoss. 1986. "FAPRI Trade Model for Soybean Sector: Specification, Estimation, and Validation." CARD 86-SR2. Center for Agricultural and Rural Development, Iowa State University, Ames.

Mittlehammer, Ron C., S. C. Matulich, and D. Bushaw. 1981. "On Implicit Forms of Multiproduct-Multifactor Production Functions." American Journal of Agricultural Economics 63: 164-168.

Morey, E. R. 1986. "An Introduction to Checking, Testing, and Imposing Curvature Properties: The True Functions and the Estimated Functions." Canadian Journal of Economics 19: 207-235.

Mortensen, D. T. 1973. "Generalized Costs of Adjustment and Dynamic Factor Demand Theory." Econometrica 42: 657-664.

Morzuch, B. J., R. D. Weaver, P. G. Helmberger. 1980. "Wheat Acreage Supply Response under Changing Farm Programs." American Journal of Agricultural Economics 64: 29-37.

Moschini, Giancarlo. 1988a. "A Model of Production with Supply Management for the Canadian Agricultural Sector." American Journal of Agricultural Economics 70: 318-329.

Moschini, Giancarlo. 1988b. "The Cost Structure of Ontario Dairy Farms: A Microeconometric Analysis." Canadian Journal of Agricultural Economics 36: 187-206.

Muth, John F. 1961. "Rational Expectations and the Theory of Price Movements." Econometrica 29: 315-335.

Narayana, N. S. S., and K. Parikh. 1988. "Estimation of Yield Functions for Major Cereals in India." Indian Journal of Quantitative Economics 4: 102-112.

Paarlberg, D. 1980. Farm and Food Policy: Issues for the 1980's. Lincoln: University of Nebraska Press.

Parikh, K. S., and F. Rabar, eds. 1981. Food for All in a Substainable World: The IIASA Food and Agriculture Program. Laxemberg, Austria: International Institute for Analysis.

Parikh, K. S., G. Fisher, K. Frohberg, and O. Gulbrandsen. 1988. Toward Free Trade in Agriculture. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Piggot, John, and John Whalley, eds. 1985. New Developments in Applied General Equilibrium Analysis. New York: Cambridge University Press.

Pindyck, Robert S., and Daniel L. Rubinfeld. 1981. Econometric Models and Economic Forecasts. New York: McGraw-Hill Book COmpany.

Pope, Rulon D. 1980. "The Generalized Envelope Theorem and Price Uncertainty." International Economic Review 21: 75-86.

Pope, Rulon D. 1982. "To Dual or Not to Dual." Western Journal of Agricultural Economics 7: 337-351.

Pope, Rulon D., and Robert Chambers. 1988. "Price Aggregation when Price Taking Firm's Prices Vary." Mimeo. Brigham Young University, Provo, Utah.

Pope, Rulon, D., and Arne Hallam. 1988a. "Testing Separability of Production Using Flexible Functional Form Profit Functions." Economics Letters 26: 265-270.

Pope, Rulon, D., and Arne Hallam. 1988b. "Testing Separability in Production Economics." American Journal of Agricultural Economics 70: 142-151.

Pollak, Robert A., and Terence J. Wales. 1987. "Specification and Estimation of Nonseparable Two-stage Technologies: The Leontief CES and the Cobb Douglas CES." Journal of Political Economy 95: 311-333.

Powell, M. J. D. 1971. "Recent Advances in Unconstrained Optimaization." Mathematical Programming 1: 26-57.

Pyatt, Graham. 1988. "A SAM Approach to Modeling." Journal of Policy Modeling 10: 327-352.

Pyatt, Graham, and J. I. Round. 1977. "Social Accounting Matrices for Development Planning." Review of Income and Wealth 23: 339-364.

Pyatt, Graham, and Jeffery I. Round. 1979. "Accounting and Fixed-Price Multipliers in a Social Accounting Matrix Framework." Economic Journal 89: 850-73.

Pyatt, Graham, and Jeffery I. Round, eds. 1985. Social Accounting Matrices: A basis for planning. Washington, D.C.: The World Bank.

Rausser, G. C., and J. W. Freebairn. 1974. "Estimating of Policy Preference Functions: An Application to U.S. Beef Import Quotas." Review of Economics and Statistics 56: 437-449.

Ray, Subash C. 1982. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77." American Journal of Agricultural Economics 64: 490-498.

Robinson, Sherman. 1986. Multisectoral Models of Developing Countries: A Survey." Working Paper No. 401. Department of Agricultural and Resource Economics, University of California, Berkeley.

Robinson, Sherman, and David Roland-Holst. 1988. "Macroeconomic Structure and Computable General Equilibrium Approaches." Journal of Policy Modeling 10: 353-376.

Robinson, Sherman, Maureen Kilkenny, and Irma Adelman. 1988. "The Effects of Trade Liberalization in Agriculture on the U.S. Economy: Projections to 1991." Working Paper No. 465. Department of Agricultural and Resource Economics, Giannini Foundation of Agricultural Economics, University of California, Berkeley.

Rossi, Nicola. 1984. "The Estimation of Product Supply and Input Demand by the Differential Approach." American Journal of Agricultural Economics 66: 368-375.

Rossi, Peter E. 1985. "Comparison of Alternate Functional Forms in Production." Journal of Econometrics 30: 345-361.

Sakai, Yasuhiro. 1974. "Substitution and Expansion Effects in Production Theory: The Case of Joint Production." Journal of Economic Theory 9: 255-274.

Sandmo, A. 1971. "On the Theory of the Competitive Firm under Price Uncertainty." American Economic Review 61: 65-73.

Sargent, J. 1976. "A Classical Macroeconometric Model for the United States." Journal of Political Economy 84: 207-238.

Scarf, H., and T. Hansen. 1973. The Computation of Economic Equilibria. New Haven: Yale University Press.

Schmitz, Andrew, and Robert G. Chambers. 1986. "Welfare and Trade Effects of Deficiency Payments." Journal of Agricultural Economics 37: 37-43.

Schuh, E. G. 1974. "The Exchange Rate and U.S. Agriculture." American Journal of Agricultural Economics 56: 1-13.

Shei, Shun-Yi. 1978. "The Exchange Rate and United States Agricultural Product Market: A General Equilibrium Approach." Unpublished Ph.D. dissertation. Purdue University, West Lafayette.

Shoven, John B., and John Whalley. 1984. "Applied General Equilibrium Models of Taxation and International Trade." Journal of Economic Literature 22: 1007-1051.

Shumway, Richard C. 1983. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops." American Journal of Agricultural Economics 65: 748-760.

Shumway, Richard C., and W. P. Alexander. 1988. "Agricultural Product Supplies and Input Demands: Regional Comparisons." American Journal of Agricultural Economics 70: 153-161.

Shumway, Richard C., and Anne Chang. 1980. "Supply Response of Texas Field Crops: An Evaluation of the CET Linear Supply Model." Western Journal of Agricultural Economics 5: 149-164.

Shumway, Richard C., K. Jegasothy and W. P. Alexander. 1987. "Production Interrelationships in Sri Lankan Agriculture." Australian Journal of Agricultural Economics 31: 16-28.

Shumway, Richard C., Rulon Pope, and E. Nash. 1984. "Allocatable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling." American Journal of Agricultural Economics 66: 72-78.

Shumway, Richard C., R. R. Saez, and P. E. Gottret. 1988. "Multiproduct Supply and Input Demand in U.S. Agriculture." American Journal of Agricultural Economics 70: 330-37.

Sidhu, Surjit S., and Carlos A. Baanante. 1981. "Estimating Farm level Input Demand and Wheat Supply in the Indian Punjab Using a Translog Profit Function." American Journal of Agricultural Economics 63: 237-246.

Silberberg, E. 1978. The Structure of Economics: A Mathematical Analysis. New York: McGraw-Hill Book Company.

Skold, Karl D., and Patrick Westhoff. 1988. "An Analysis of Corn and Soybean Supply Response to Changing Government Programs." Working Paper 88-WP34. Center for Agricultural and Rural Development, Iowa State University. Ames, Iowa.

Slemod, Joel. 1983. "A General Equilibrium Model of Taxation with Endogenous Behavior." In Behavioral Simulation Models in Tax Policy Analysis. Edited by Martin Feldstein. Chicago: The University of Chicago Press.

Sopher, C. C., and R. McCracken. 1973. "Relationships Between Individual Soil Properties, Managment Prctices and Corn Yields on Slelcted South Atlantic Coastal Plain Soils." Agronomy Journal 65: 6595-599.

Squires, Dale. 1987. "Long-Run Profit Functions for Multiproduct Firms." American Journal of Agricultural Economics 69: 558-569.

Srinivasan, T. N., and John Whalley. 1986. General Equilibrium Trade Policy Modelling. Cambridge: The MIT Press.

Stamoalis, Kostas G., James, A. Chalfant, and Gordon C. Rausser. 1985. "Monetary Policies and the Overshooting of Flexible Prices: Implications for Agricultural Policy." Working Paper No. 372. Department of Agricultural and Resource Economics, University of California, Berkeley.

Stone, J. R. N. 1966. "The Social Accounts from a Consumer Point of View." Review of Income and Wealth 12: 1-33.

Stone, J. R. N. 1985. "The Disaggregation of the Household Sector in the National Accounts." In G. Fyatt and J. I. Round, eds. Social Accounting Matrices: A Basis for Planning. Washington, D. C.: World Bank.

Talpaz, H., W. P. Alexander, and C. R. Shumaway. 1987. "Estimation of Systems of Equations Subject to Curvature Constraints." Texas Agricultural Experimental Station Technical Article No. 21966. College Station, Texas.

Taylor, Lance, and Stephen L. Black. 1974. "Practical General Equilibrium Estimation of Resource Pulls Under Trade Liberalization." Journal of International Economics 4: 37-58.

Taylor, Robert. 1984. "Stochatic Dynamic Duality: Theory and Empirical Applicability." American Journal of Agricultural Economics 66: 351-358.

Taylor, Robert. 1987a. "AGSIM: The Crop Supply Component." Staff Paper No. 87E-386. Department of Agricultural Economics, University of Illinois, Urbana.

Taylor, Robert. 1987b. "AGSIM: User's Manual. Version 87.3." Staff Paper No. 87E-394. Department of Agricultural Economics, University of Illinois, Urbana.

Taylor, T., and M. J. Monson. 1985. "Dynamic Factor Demands for Aggregate Southeastern United States Agriculture." Southern Journal of Agricultural Economics 17: 1-9.

Thirtle, Colin G. 1985. "Technological Change and the Productivity Slowdown in Field Crops: United States, 1939-78." Southern Journal of Agricultural Economics 17: 33-42.

Thompson, Gary, D. 1988. "Choice of Flexible Functional Forms: Review and Appraisal." Western Journal of Agricultural Economics 13: 169-183.

Tims, Wouter, and Jean Waelbroeck. 1982. "Global Modeling in the World Bank 1973-83." World Bank Staff Working Paper No. 544.

Tornquist, L. 1936. "The Bank of Finland's Consumption Price Index." Bank of Finland Monthly Bulletin 10: 1-8.

Traill, W. B. 1982. The Effect of Price Support Policies on Agricultural Investment, Employment, Farm Incomes, and Land Values in the U.K." Journal of Agricultural Economics 33: 369-385.

Trivedi, P. K. 1981. "Some Discrete Approximations to Divisia Integral Indices." International Economic Review 22: 71-77.

Tyers, Rodney. 1985. "International Impacts of Protection: Model Structure and Results for Economic Agricultural Policy." Journal of Policy Modeling 7: 219-251.

U. S. Department of Agriculture. Agricultural Statistics. Various Issues.

U. S. Department of Agriculture. 1984. "History of Agricultural Price-Support and Adjustment Programs: Background for 1985 Farm Legislation." Economic Research Service, Agricultural Information Bulletin No. 485.

U. S. Department of Agriculture. 1985. Possible Economic Consequences of Reverting to Permanent Legislation or Eliminating Price and Income Supports. Economic Research Service, Agricultural Economic Report No. 526.

U. S. Department of Agriculture. 1986. "Economic Indicators of the Farm Sectors: National Financial Summary." Economic Research Service, ECIFS6-2.

U. S. Department of Agriculture. 1987. "Rice: Summary of 1987 Support Program and Related Information." ASCS Commodity Fact Sheet, Agricultural Stabilization and Conservation Service.

Varian, Hal R. 1984. Microeconomic Analysis. New York: W. W. Norton and Company.

Vartia, Y. P. 1983. "Efficient Methods of Measuring Welfare Change and Compensated Income in Terms of Ordinary Demand Functions." Econometrica 51: 79-98.

Vasavada, Utpal, and Robert G. Chambers. 1986. "Investment in U. S. Agriculture." American Journal of Agricultural Economics 68: 950-960.

Waelbroeck, Jean. 1986. "Some Pitfalls in Applied General Equilibrium Modeling." Discussion Paper No. 86-01. Department of Economics, University of British Columbia, Vancouver, Canada.

Weaver, Robert D. 1983. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region." American Journal of Agricultural Economics 65: 45-56.

Westcott, Paul C., and David B. Hull. 1985. "A Quarterly Forecasting Model for U. S. Agriculture: Subsector Models for Corn, Wheat, Soybeans, Cattle, Hogs, and Poultry." Technical Bulletin No. 1700. Economic Research Service, United States Department of Agricultre.

Westhoff, Patrick, and Karl D. Skold. 1987. "The Impacts of Two Policies to Reduce Excess Supplies of Corn and the Cost of Government Programs." Paper presented at the annual meetings of the American Agricultural Economics Association, East Lansing, Michigan, August 2-1.

Whalley, John. 1980. Discriminatory Features of Domestic Factor Tax Systems in a Goods Mobile-Factors Immobile Trade Model: An Empirical General Equilibrium Approach. Journal of Political Economy 88: 1177-1202.

Whalley, John. 1984. "The North South Debate and Terms of Trade: An Applied General Equilibrium Approach." Review of Economics and Statistics 66: 224-234.

Whalley, John. 1985a. Trade Liberalization Among World Trading Areas. Cambridge: The MIT Press.

Whalley, John. 1985b. "Hidden Challenges in Recent Applied General Equilibrium Analysis. In New Development in Applied General Equilibrium Analysis, eds. J. Pigott and J. Whalley. New York: Cambridge University Press. pp. 25-44.

Whalley, John, and Bernard Yeung. 1984. "External Sector Closing Rules in Applied General Equilibrium Models." Journal of International Economics 16: 123-138.

Winters, Alan L. 1987. "The Economic Consequences of Agricultural Support: A Survey." CPE/WP1 (87)3, Organization for Economic Cooperation and Development, Paris.

Yanagida, John F., A. Azzam, and D. Linsenmeyer. 1987. "Two Alternative Methods of Removing Price Supports: Implications to the U.S. Corn and Livestock Industries." Journal of Policy Modeling 9: 331-320.

Zalai, Erno. 1982. "Computable General Equilibrium Models: An Optimal Planning Perspective." Mathematical Modeling 3: 437-451.

ACKNOWLEDGMENTS

I wish to express my deep sense of appreciation to my major professor Dr. Stanley R. Johnson for his immense contribution to my academic training and professional development. His constant encouragement and inspiration are invaluable. Dr. William Meyers, my co-major professor, deserves a special thanks. I thank Dr. Fox, Dr. Fuller, and Dr. Falk for serving on my committee. They have been very helpful.

Dr. Klaus Frohberg deserves special gratitude. He has been a constant source of help and assistance through out the study. I am thankful to Dr. Giancarlo Moschini for his generous help. I would also like to thank my friends K. Eswaramoorhty, Matthew Holt, and Patrick Westhoff for their help. I wish to express my sincere gratitude to the Center for Agricultural and Rural Development at Iowa State University for providing me with financial assistance during the course of this research.

Finally, I wish to express my appreciation and thanks to my wife Ranga for her love and compassion. She is just marvelous. But for her patience, understanding, and encouragement I would not have completed this dissertation.

APPENDIX A

Table A.1. Data used for estimation[a]

YEAR	WHEPD	RICPD	CORPD	OCGPD	SOYPD	HAYPD	COTPD	PNTPD	FXSPD
1950	1019	38.82	2764	1349.42	299	103.82	4804.8	2035	134.50
1951	988	46.09	2629	1187.10	284	109.50	7272.0	1679	116.04
1952	1306	48.19	2981	1042.49	299	106.39	7267.2	1356	100.94
1953	1173	52.83	2882	1053.53	269	108.25	7905.6	1574	125.93
1954	984	64.19	2708	1369.10	341	107.83	6576.0	1008	138.03
1955	937	55.90	2873	1545.00	373	112.81	7065.6	1548	135.19
1956	1006	49.46	3075	1266.68	449	107.98	6388.8	1607	157.35
1957	956	42.94	3045	1780.13	483	120.04	5260.8	1436	84.16
1958	1458	44.76	3356	1896.64	580	120.10	5524.8	1814	125.23
1959	1118	53.65	3825	1588.93	533	110.98	6988.8	1523	71.28
1960	1355	54.59	3907	1733.00	555	118.16	6849.6	1718	101.92
1961	1233	54.20	3598	1472.64	678	116.96	6873.6	1657	74.51
1962	1092	66.05	3606	1549.03	669	121.76	7137.6	1719	108.21
1963	1147	70.27	4019	1551.58	699	117.54	7358.4	1942	105.23
1964	1283	73.17	3484	1386.04	701	118.78	7272.0	2099	82.88
1965	1315	76.28	4103	1616.94	846	125.61	7171.2	2390	110.24
1966	1305	85.02	4167	1574.87	928	120.93	4588.8	2416	81.88
1967	1507	98.28	4860	1585.60	976	125.13	3571.2	2477	80.15
1968	1557	104.14	4450	1707.78	1107	124.24	5246.4	2547	100.11
1969	1443	91.90	4687	1723.90	1133	126.03	4795.2	2535	127.86
1970	1352	83.81	4152	1641.99	1127	126.97	4891.2	2983	110.39
1971	1619	85.77	5646	1864.78	1176	129.12	5030.4	3005	88.82
1972	1546	85.44	5580	1634.11	1271	128.57	6576.0	3275	87.91
1973	1711	92.77	5671	1735.07	1547	134.22	6225.6	3474	102.35
1974	1782	112.39	4701	1275.72	1216	126.38	5539.2	3668	82.92
1975	2127	128.44	5841	1505.53	1548	132.40	3984.0	3847	103.96
1976	2149	115.65	6289	1404.95	1289	120.13	5078.4	3739	78.68
1977	2046	99.22	6505	1652.53	1767	132.21	6907.2	3715	219.92
1978	1776	133.17	7268	1535.04	1869	143.82	5212.8	3952	269.52
1979	2134	131.95	7928	1507.78	2261	147.31	7022.4	3968	498.64
1980	2381	146.15	6639	1212.44	1798	130.74	5337.6	2303	262.17
1981	2785	182.74	8119	1635.77	1989	142.52	7512.0	3982	306.46
1982	2765	153.64	8235	1694.43	2190	149.24	5740.8	3440	370.40
1983	2420	99.72	4175	1271.53	1636	140.76	3729.6	3296	224.75
1984	2595	138.81	7674	1726.07	1861	150.65	6230.4	4405	259.51
1985	2425	134.91	8877	1978.50	2099	148.60	6446.4	4122	227.59
1986	2087	134.42	8253	1742.02	2007	155.27	4670.4	3700	209.72

[a]see Table 5.1 for variable explanations.

Table A.1. continued

YEAR	SUGPD	TOBPD	VEGPD	FUNPD	LNDUS	FERUS	OPCUS	LABUS
1950	316.80	2029.56	15.20	1188	-360.23	-4.06	-2657.8	-6922
1951	268.91	2331.59	16.76	1260	-371.00	-4.73	-2681.3	-7204
1952	277.52	2256.07	16.37	1203	-364.61	-5.20	-2848.2	-6850
1953	313.73	2059.23	16.95	1246	-368.51	-5.65	-2938.7	-6627
1954	332.19	2243.74	16.26	1234	-363.50	-5.90	-2960.5	-6238
1955	313.66	2192.85	16.65	1263	-362.80	-6.12	-3187.5	-6012
1956	319.33	2175.26	19.11	1303	-352.86	-6.06	-3395.6	-5574
1957	353.26	1667.54	16.95	1275	-338.19	-8.14	-3075.3	-5001
1958	330.36	1736.42	19.03	1237	-332.07	-6.51	-3308.1	-4818
1959	373.05	1796.42	17.26	1358	-335.43	-7.41	-3662.7	-4771
1960	366.75	1944.18	18.40	1298	-330.02	-7.46	-3701.6	-4590
1961	411.05	2061.40	18.85	1345	-340.07	-7.84	-3784.3	-4370
1962	419.07	2314.78	20.04	1353	-344.90	-8.45	-3907.6	-4190
1963	523.16	2343.80	19.02	1300	-343.24	-9.51	-4103.8	-4088
1964	537.86	2227.93	18.66	1300	-347.46	-10.40	-4232.7	-3867
1965	480.30	1854.57	19.26	1425	-353.03	-10.99	-4230.3	-3416
1966	487.51	1884.63	19.56	1536	-350.26	-12.44	-4242.7	-3142
1967	494.56	1967.91	21.12	1609	-345.49	-13.97	-4714.4	-3104
1968	561.33	1710.35	23.40	1477	-347.61	-15.04	-4706.5	-3013
1969	580.18	1803.27	20.47	1794	-353.12	-15.52	-4722.5	-2973
1970	548.30	1906.45	20.66	1711	-357.08	-16.07	-5133.1	-2788
1971	569.60	1704.88	21.28	1839	-351.88	-17.17	-5874.9	-2757
1972	628.69	1749.09	21.82	1664	-366.96	-17.22	-5836.1	-2621
1973	555.98	1742.11	22.57	1991	-346.81	-18.03	-6465.8	-2667
1974	516.46	1989.73	23.81	1970	-337.34	-19.34	-6521.3	-2657
1975	641.23	2182.30	25.53	2113	-342.70	-17.56	-6007.0	-2630
1976	633.46	2136.67	23.56	2113	-349.76	-20.85	-6463.5	-2556
1977	565.63	1914.12	25.35	2174	-358.14	-22.11	-6446.8	-2530
1978	566.87	2024.82	24.46	2091	-369.34	-20.57	-7255.4	-2449
1979	524.73	1526.52	26.06	2150	-373.00	-22.57	-7771.1	-2432
1980	545.20	1786.23	24.15	2485	-366.89	-23.08	-7414.8	-2442
1981	600.19	2063.59	24.27	2250	-374.66	-23.68	-7064.4	-2442
1982	540.48	1994.49	21.54	2172	-382.21	-21.42	-6636.3	-2369
1983	529.75	1428.97	20.17	2176	-398.66	-18.10	-7028.6	-2135
1984	532.23	1727.96	22.87	2018	-389.20	-21.79	-7068.4	-2266
1985	545.77	1511.64	22.69	1976	-387.81	-21.66	-7178.0	-2170
1986	599.67	1165.93	22.27	1957	-386.20	-19.70	-6412.0	-2074

Table A.1. continued

YEAR	WHEFP	RICFP	CORFP	OCGFP	SOYFP	HAYFP	COTFP	PNTFP	FXSFP
1950	2.00	5.09	1.53	1.26	2.47	21.10	0.40	0.109	1.000
1951	2.11	4.82	1.66	1.36	2.73	25.70	0.38	0.104	1.114
1952	2.09	5.87	1.53	1.39	2.72	26.90	0.35	0.109	1.116
1953	2.04	5.19	1.49	1.25	2.72	21.90	0.32	0.111	1.090
1954	2.12	4.56	1.43	1.19	2.46	21.90	0.34	0.122	0.913
1955	1.98	4.81	1.35	0.99	2.22	22.50	0.32	0.117	0.868
1956	1.97	4.86	1.29	1.13	2.18	22.20	0.32	0.112	0.895
1957	1.93	5.11	1.11	0.99	2.07	19.30	0.30	0.104	0.880
1958	1.75	4.68	1.12	0.98	2.00	18.80	0.33	0.106	0.806
1959	1.76	4.59	1.05	0.97	1.96	22.30	0.32	0.096	0.898
1960	1.74	4.55	1.00	0.92	2.13	21.70	0.30	0.100	0.794
1961	1.83	5.14	1.10	1.05	2.28	20.70	0.33	0.109	0.976
1962	2.04	5.04	1.12	1.02	2.34	21.80	0.32	0.110	0.849
1963	1.85	5.01	1.11	1.00	2.51	24.60	0.32	0.112	0.826
1964	1.37	4.90	1.17	1.05	2.62	23.90	0.31	0.112	0.843
1965	1.35	4.93	1.16	1.04	2.54	23.20	0.29	0.114	0.840
1966	1.63	4.95	1.24	1.09	2.75	25.00	0.22	0.113	0.870
1967	1.39	4.97	1.03	1.06	2.49	24.50	0.27	0.114	0.872
1968	1.24	5.00	1.08	0.98	2.43	23.60	0.23	0.119	0.825
1969	1.25	4.95	1.16	1.02	2.35	24.70	0.22	0.123	0.785
1970	1.33	5.17	1.33	1.09	2.85	26.10	0.22	0.128	0.723
1971	1.34	5.34	1.08	1.04	3.03	28.10	0.28	0.136	0.724
1972	1.76	6.73	1.57	1.30	4.37	31.30	0.27	0.145	0.840
1973	3.95	13.80	2.55	2.13	5.68	41.60	0.45	0.162	1.811
1974	4.09	11.20	3.02	2.77	6.64	50.90	0.43	0.179	2.649
1975	3.55	8.35	2.54	2.43	4.92	52.10	0.51	0.196	1.799
1976	2.73	7.02	2.15	2.27	6.81	60.20	0.64	0.200	1.880
1977	2.33	9.49	2.02	1.84	5.88	53.70	0.52	0.210	1.575
1978	2.97	8.16	2.25	2.01	6.66	49.80	0.58	0.211	1.699
1979	3.80	10.50	2.48	2.33	6.29	59.40	0.63	0.206	1.450
1980	3.99	12.80	3.12	2.91	7.60	71.00	0.75	0.251	1.768
1981	3.69	9.05	2.47	2.54	6.07	67.30	0.54	0.269	1.712
1982	3.45	8.11	2.55	2.43	5.71	69.30	0.59	0.251	1.397
1983	3.51	8.76	3.21	2.69	7.83	75.80	0.66	0.241	2.073
1984	3.39	8.06	2.63	2.46	5.84	72.40	0.58	0.279	1.723
1985	3.08	6.62	2.23	2.03	5.05	67.60	0.57	0.243	1.216
1986	2.42	3.93	1.55	1.60	4.80	60.10	0.52	0.288	1.076

Table A.1. continued

YEAR	SUGFP	TOBFP	VEGFP	FUNFP	RENT	FERFP	OPCFP	WAGE
1950	1.000	0.52	54.849	1.00	3.71	213.79	1.000	0.69
1951	0.940	0.51	63.338	0.92	4.10	202.75	1.049	0.77
1952	0.988	0.50	68.252	0.91	4.22	207.31	1.109	0.81
1953	0.992	0.52	59.956	0.96	4.21	194.51	1.082	0.82
1954	0.942	0.51	61.039	0.99	4.36	192.54	1.051	0.81
1955	0.933	0.53	63.670	1.01	4.63	180.72	1.052	0.82
1956	1.046	0.54	60.108	1.04	5.10	177.56	1.036	0.86
1957	0.956	0.56	67.074	1.01	6.32	132.19	1.056	0.88
1958	1.007	0.60	56.068	1.13	6.87	170.97	1.053	0.92
1959	0.966	0.58	62.807	1.12	7.58	167.07	1.045	0.95
1960	0.997	0.61	61.121	1.18	8.35	167.83	1.051	0.97
1961	0.993	0.64	64.197	1.20	8.33	171.30	1.059	0.99
1962	1.090	0.59	63.242	1.17	8.63	171.12	1.062	1.01
1963	1.145	0.58	64.856	1.29	9.13	168.24	1.071	1.05
1964	0.970	0.59	70.266	1.39	9.68	170.39	1.068	1.08
1965	1.024	0.65	73.854	1.16	10.38	170.79	1.076	1.14
1966	1.105	0.71	80.285	1.14	11.43	168.65	1.074	1.23
1967	1.169	0.67	79.633	1.13	12.54	165.86	1.092	1.33
1968	1.181	0.70	76.294	1.38	14.86	154.46	1.112	1.44
1969	1.146	0.72	82.933	1.21	17.44	142.33	1.122	1.55
1970	1.270	0.73	79.545	1.21	19.89	145.61	1.077	1.64
1971	1.321	0.79	88.296	1.25	19.61	149.27	1.040	1.73
1972	1.363	0.83	95.040	1.54	20.75	152.15	1.107	1.58
1973	2.386	0.90	106.712	1.73	25.15	188.69	1.238	1.73
1974	4.402	1.09	118.225	1.75	30.38	304.96	1.598	2.25
1975	2.194	1.03	125.178	1.69	37.40	370.50	1.884	2.43
1976	1.620	1.13	129.316	1.76	44.20	300.00	1.993	2.66
1977	1.875	1.19	130.056	2.12	47.89	285.30	2.118	2.87
1978	2.000	1.32	149.685	2.76	55.78	309.24	2.209	3.09
1979	2.680	1.41	153.939	3.01	71.38	312.89	2.430	3.39
1980	3.841	1.52	168.025	2.64	88.94	392.85	2.925	3.66
1981	2.425	1.71	189.765	2.93	96.87	378.67	3.298	4.02
1982	2.763	1.76	164.956	3.15	101.07	358.96	3.462	4.00
1983	2.894	1.75	181.220	2.79	95.38	373.76	3.233	4.11
1984	2.788	1.81	180.679	3.35	84.28	327.58	3.342	4.36
1985	2.710	1.65	174.916	3.46	77.70	319.85	3.306	4.44
1986	2.738	1.53	185.010	3.53	71.04	280.00	3.132	4.70

Table A.1. continued

YEAR	WHEEP	RICEP	COREP	OCGEP	SOYEP	HAYEP	COTEP	PNTEP	FXSEP
1951	2.60	6.61	1.99	1.64	3.21	27.40	0.52	14.94	1.30
1952	2.60	5.95	2.05	1.68	3.37	31.73	0.47	14.81	1.37
1953	2.55	7.16	1.87	1.69	3.32	32.80	0.43	14.51	1.36
1954	2.52	6.41	1.84	1.55	3.36	27.04	0.40	15.06	1.35
1955	2.59	5.56	1.74	1.45	3.00	26.71	0.41	14.88	1.11
1956	2.30	5.59	1.57	1.15	2.58	26.16	0.37	13.60	1.01
1957	2.24	5.52	1.47	1.28	2.48	25.23	0.36	12.73	1.02
1958	2.10	5.55	1.21	1.08	2.27	20.98	0.33	11.59	0.96
1959	1.84	4.93	1.18	1.03	2.11	19.79	0.35	11.16	0.85
1960	1.81	4.73	1.08	1.00	2.02	22.99	0.33	10.37	0.93
1961	1.76	4.60	1.11	0.98	2.32	21.92	0.30	11.16	0.80
1962	1.94	5.09	1.14	1.04	2.26	20.50	0.33	10.96	0.97
1963	1.94	4.80	1.13	0.97	2.23	20.76	0.30	10.67	0.81
1964	1.82	4.64	1.09	0.93	2.32	22.78	0.30	10.37	0.76
1965	1.65	4.30	1.07	0.92	2.30	20.96	0.27	9.82	0.74
1966	1.91	4.01	1.00	0.84	2.07	18.86	0.24	9.27	0.68
1967	1.23	3.72	0.96	0.82	2.07	18.80	0.17	8.53	0.65
1968	0.97	3.45	0.83	0.74	1.74	17.01	0.19	8.34	0.61
1969	1.67	3.23	0.79	0.67	1.57	15.23	0.15	7.99	0.53
1970	1.60	3.02	0.77	0.64	1.43	15.06	0.13	7.77	0.48
1971	1.65	2.99	0.78	0.64	1.65	15.09	0.13	7.76	0.42
1972	1.86	3.38	0.84	0.74	1.92	17.78	0.18	9.02	0.46
1973	1.93	3.89	0.93	0.76	2.53	18.09	0.16	9.50	0.49
1974	1.76	6.13	1.13	0.95	2.52	18.49	0.20	8.13	0.80
1975	1.68	4.61	1.24	1.14	2.73	20.95	0.18	8.12	1.09
1976	1.33	3.14	0.95	0.91	1.85	19.59	0.19	7.78	0.68
1977	0.95	2.45	0.75	0.79	2.37	20.98	0.22	7.50	0.66
1978	1.06	3.07	0.67	0.68	1.90	17.38	0.17	6.80	0.51
1979	0.96	2.41	0.66	0.63	1.96	14.69	0.17	6.22	0.50
1980	1.04	2.87	0.68	0.64	1.72	16.23	0.17	6.22	0.40
1981	0.99	3.18	0.78	0.72	1.89	17.66	0.19	6.24	0.44
1982	0.96	2.61	0.63	0.64	1.52	16.83	0.17	6.88	0.43
1983	0.95	2.76	0.65	0.60	1.39	16.86	0.18	6.69	0.34
1984	0.91	2.62	0.74	0.62	1.80	17.39	0.18	6.31	0.48
1985	0.91	2.59	0.65	0.57	1.32	16.31	0.17	6.28	0.39
1986	0.87	2.45	0.61	0.50	1.07	14.38	0.17	6.47	0.26

Table A.1. continued

YEAR	SUGEP	TOBEP	VEGEP	FUNEP
1951	1.30	0.68	71.23	129.87
1952	1.16	0.63	78.19	113.58
1953	1.20	0.61	83.23	110.98
1954	1.22	0.64	74.02	118.52
1955	1.15	0.62	74.44	120.73
1956	1.08	0.62	74.03	117.44
1957	1.19	0.61	68.30	118.18
1958	1.04	0.61	72.91	109.78
1959	1.06	0.63	59.02	118.95
1960	1.00	0.60	64.75	115.46
1961	1.01	0.62	61.74	119.19
1962	0.98	0.63	63.56	118.81
1963	1.04	0.56	60.23	111.43
1964	1.06	0.54	60.05	119.44
1965	0.85	0.52	61.64	121.93
1966	0.83	0.53	60.04	94.31
1967	0.83	0.53	60.36	85.71
1968	0.81	0.47	55.30	78.47
1969	0.76	0.45	49.22	89.03
1970	0.70	0.44	50.57	73.78
1971	0.73	0.42	45.98	69.94
1972	0.84	0.50	55.88	79.11
1973	0.79	0.48	54.94	89.02
1974	1.06	0.40	47.43	76.89
1975	1.81	0.45	48.65	72.02
1976	0.82	0.40	47.06	63.53
1977	0.56	0.40	45.06	61.32
1978	0.61	0.40	42.09	68.61
1979	0.59	0.39	44.15	81.42
1980	0.73	0.40	42.06	82.24
1981	0.96	0.40	41.80	65.67
1982	0.61	0.43	47.44	73.25
1983	0.67	0.43	40.14	76.64
1984	0.66	0.40	41.56	63.99
1985	0.63	0.41	40.69	75.45
1986	0.58	0.35	37.22	73.62

Table A.1. continued

YEAR	WHETP	RICTP	CORTP	OCGTP	COTTP	TOBTP
1950	0.00	4.56	0.00	0.000	0.28	0.46
1951	0.00	5.00	0.00	0.000	0.30	0.51
1952	0.00	5.04	0.00	0.000	0.31	0.51
1953	0.00	4.84	0.00	0.000	0.31	0.48
1954	0.00	4.92	0.00	0.000	0.32	0.47
1955	0.00	4.66	0.00	0.000	0.32	0.47
1956	0.00	4.57	0.00	0.000	0.29	0.49
1957	0.00	4.72	0.00	0.000	0.29	0.52
1958	0.00	4.48	0.00	0.000	0.31	0.55
1959	0.00	4.38	0.00	0.000	0.30	0.57
1960	0.00	4.42	0.00	0.000	0.29	0.57
1961	0.00	4.71	0.00	0.000	0.32	0.57
1962	0.00	4.71	0.00	0.000	0.32	0.57
1963	0.00	4.71	1.25	1.000	0.32	0.58
1964	2.00	4.71	1.25	1.000	0.33	0.58
1965	2.00	4.50	1.25	1.000	0.33	0.59
1966	2.57	4.50	1.30	1.032	0.30	0.60
1967	2.61	4.55	1.35	1.077	0.31	0.61
1968	2.63	4.60	1.35	1.077	0.32	0.63
1969	2.77	4.72	1.35	1.077	0.34	0.65
1970	2.82	4.86	1.35	1.077	0.37	0.68
1971	2.93	5.07	1.35	1.112	0.35	0.71
1972	3.02	0.00	1.41	1.202	0.36	0.74
1973	3.39	0.00	1.64	1.315	0.42	0.78
1974	2.05	0.00	1.38	1.177	0.38	0.85
1975	2.05	0.00	1.38	1.177	0.38	0.95
1976	2.29	8.25	1.57	1.337	0.43	1.08
1977	2.90	8.25	2.00	2.110	0.48	1.16
1978	3.40	8.53	2.10	2.145	0.52	1.23
1979	3.40	9.05	2.20	2.231	0.58	1.31
1980	3.63	9.49	2.05	2.262	0.58	1.46
1981	3.81	10.67	2.40	2.429	0.71	1.62
1982	4.05	10.85	2.70	2.459	0.71	1.73
1983	4.30	11.40	2.86	2.543	0.76	1.73
1984	4.38	11.90	3.03	2.610	0.81	1.73
1985	4.38	11.90	3.03	2.610	0.81	1.60
1986	4.38	11.90	3.03	2.610	0.81	1.47

Table A.1. continued

YEAR	WHELR	RICLR	CORLR	OCGLR	SOYLR	PNTLR
1950	1.99	0.00	1.47	1.117	2.06	0.11
1951	2.18	0.00	1.57	1.155	2.45	0.12
1952	2.20	0.00	1.60	1.256	2.56	0.12
1953	2.21	0.00	1.60	1.285	2.56	0.12
1954	2.24	0.00	1.62	1.204	2.22	0.12
1955	2.08	0.00	1.58	0.976	2.04	0.12
1956	2.00	0.00	1.50	1.048	2.15	0.11
1957	2.00	0.00	1.40	0.981	2.09	0.11
1958	1.82	0.00	1.36	0.971	2.09	0.11
1959	1.81	0.00	1.12	0.802	1.85	0.10
1960	1.78	0.00	1.06	0.802	1.85	0.10
1961	1.79	0.00	1.20	0.995	2.30	0.11
1962	2.00	0.00	1.20	0.995	2.25	0.11
1963	1.82	0.00	1.07	1.000	2.25	0.11
1964	1.30	0.00	1.10	0.960	2.25	0.11
1965	1.25	0.00	1.05	0.895	2.25	0.11
1966	1.25	0.00	1.00	0.866	2.50	0.11
1967	1.25	0.00	1.05	0.926	2.50	0.11
1968	1.25	0.00	1.05	0.926	2.50	0.12
1969	1.25	0.00	1.05	0.909	2.25	0.12
1970	1.25	0.00	1.05	0.909	2.25	0.13
1971	1.25	0.00	1.05	0.887	2.25	0.13
1972	1.25	5.27	1.05	0.904	2.25	0.14
1973	1.25	6.07	1.05	0.904	2.25	0.16
1974	1.37	7.54	1.10	0.937	2.25	0.18
1975	1.37	8.52	1.10	0.937	0.00	0.20
1976	2.25	6.19	1.50	1.269	2.50	0.21
1977	2.25	6.19	2.00	1.719	3.50	0.22
1978	2.35	6.40	2.00	1.719	4.50	0.21
1979	2.50	6.79	2.10	1.806	4.50	0.21
1980	3.00	7.12	2.25	1.934	5.02	0.23
1981	3.20	8.01	2.40	2.062	5.02	0.23
1982	3.55	8.14	2.55	2.190	5.02	0.28
1983	3.65	8.14	2.65	2.276	5.02	0.28
1984	3.30	8.00	2.55	2.190	5.02	0.28
1985	3.30	8.00	2.55	2.190	5.02	0.28
1986	2.40	7.20	1.92	1.646	4.77	0.30

Table A.1. continued

YEAR	WHEPAR	CORPAR	OCGPAR	RICPAR	COTPAR
1950	0.000	0.000	0.000	0.000	0.000
1951	0.000	0.000	0.000	0.000	0.000
1952	0.000	0.000	0.000	0.000	0.000
1953	0.000	0.000	0.000	0.000	0.000
1954	0.000	0.000	0.000	0.000	0.000
1955	0.000	0.000	0.000	0.000	0.000
1956	0.000	0.000	0.000	0.000	0.000
1957	0.000	0.000	0.000	0.000	0.000
1958	0.000	0.000	0.000	0.000	0.000
1959	0.000	0.000	0.000	0.000	0.000
1960	0.000	0.000	0.000	0.000	0.000
1961	0.000	0.508	0.654	0.000	0.000
1962	0.751	0.506	0.465	0.000	0.000
1963	0.460	0.513	0.475	0.000	0.000
1964	0.741	0.516	0.498	0.000	0.000
1965	0.820	0.559	0.534	0.000	0.000
1966	0.820	0.488	0.496	0.000	0.000
1967	0.000	0.388	0.472	0.000	0.000
1968	0.000	0.521	0.571	0.000	0.000
1969	0.880	0.564	0.518	0.000	0.000
1970	0.879	0.546	0.507	0.000	0.000
1971	0.949	0.553	0.614	0.000	0.000
1972	0.953	0.752	0.799	0.000	0.000
1973	0.968	0.499	0.535	0.000	0.000
1974	0.000	0.000	0.000	0.000	0.000
1975	0.000	0.000	0.000	0.000	0.000
1976	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000
1978	0.878	0.504	0.877	0.000	0.000
1979	0.627	0.235	0.578	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.000	0.000	0.000	0.000
1982	0.428	0.261	0.306	0.779	0.840
1983	0.524	0.427	0.351	0.977	0.930
1984	0.509	0.478	0.291	0.845	0.700
1985	0.635	0.646	0.407	0.901	0.820
1986	0.764	0.807	0.557	0.931	0.930

Table A.1. continued

YEAR	WHESET	CORSET	OCGSET	RICSET	COTSET
1950	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00
1978	0.16	0.08	0.09	0.00	0.00
1979	0.16	0.08	0.11	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00
1982	0.15	0.10	0.10	0.23	0.12
1983	0.19	0.12	0.11	0.20	0.19
1984	0.19	0.10	0.10	0.32	0.22
1985	0.20	0.10	0.10	0.26	0.19
1986	0.23	0.16	0.18	0.35	0.24

Table A.1. continued

YEAR	WHEDIV	RICDIV	CORDIV	OCGDIV	COTDIV
1950	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.43	0.46	0.00
1962	0.26	0.00	0.46	0.46	0.00
1963	0.28	0.00	0.37	0.37	0.00
1964	0.13	0.00	0.48	0.49	0.00
1965	0.16	0.00	0.48	0.47	0.00
1966	0.20	0.00	0.54	0.52	0.00
1967	0.00	0.00	0.46	0.35	0.00
1968	0.00	0.00	0.54	0.50	0.00
1969	0.24	0.00	0.53	0.54	0.00
1970	0.39	0.00	0.53	0.52	0.00
1971	0.23	0.00	0.29	0.29	0.00
1972	0.34	0.00	0.37	0.37	0.00
1973	0.41	0.00	0.13	0.16	0.00
1974	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00
1978	0.02	0.00	0.08	0.03	0.00
1979	0.02	0.00	0.06	0.02	0.00
1980	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00
1983	0.07	0.31	0.17	0.16	0.29
1984	0.12	0.00	0.00	0.00	0.00
1985	0.12	0.15	0.00	0.00	0.09
1986	0.06	0.00	0.03	0.03	0.00

Table A.1. continued

YEAR	WHEDPA	RICDPA	CORDPA	OCGDPA	COTDPA
1950	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00
1953	0.00	0.00	0.00	0.00	0.00
1954	0.00	0.00	0.00	0.00	0.00
1955	0.00	0.00	0.00	0.00	0.00
1956	0.00	0.00	0.00	0.00	0.00
1957	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.62	0.60	0.00
1962	1.21	0.00	0.61	0.56	0.00
1963	0.88	0.00	0.41	0.33	0.00
1964	0.26	0.00	0.56	0.48	0.00
1965	0.20	0.00	0.55	0.46	0.00
1966	0.12	0.00	0.34	0.26	0.00
1967	0.00	0.00	0.25	0.12	0.00
1968	0.00	0.00	0.33	0.25	0.00
1969	0.23	0.00	0.35	0.22	0.00
1970	0.14	0.00	0.31	0.21	0.00
1971	0.00	0.00	0.00	0.00	0.00
1972	0.22	0.00	0.16	0.15	0.00
1973	0.45	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00
1978	0.40	0.00	2.05	1.32	0.00
1979	0.00	0.00	0.96	1.33	0.00
1980	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00
1983	2.65	6.61	1.47	1.23	0.53
1984	2.70	0.00	0.00	0.00	0.00
1985	2.64	3.22	0.00	0.00	0.26
1986	1.66	0.00	0.63	0.70	0.00

APPENDIX B

Mapping of b_{ij} parameters into Cholesky parameters (L_{ij} and D_{ii}):

$$
\begin{bmatrix}
b_{11} & b_{12} & \cdots\cdots & b_{1m} \\
b_{21} & b_{22} & \cdots\cdots & b_{2m} \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
b_{m1} & b_{m2} & \cdots\cdots & b_{mm}
\end{bmatrix}
=
\begin{bmatrix}
D_{11} & L_{21}D_{11} & \cdots\cdots & L_{m1}D_{11} \\
L_{21}D_{11} & L_{21}L_{21}D_{11}+D_{22} & \cdots\cdots & L_{21}L_{m1}D_{11}+L_{m2}D_{22} \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
L_{m1}D_{11} & L_{21}L_{m1}D_{11}+L_{m2}D_{22} & \cdots\cdots & L_{21}L_{21}D_{11}+L_{22}L_{22}D_{22}+\cdots+D_{mm}
\end{bmatrix}
$$

$$B \qquad = \qquad L\ D\ L'$$